COMBUSTION

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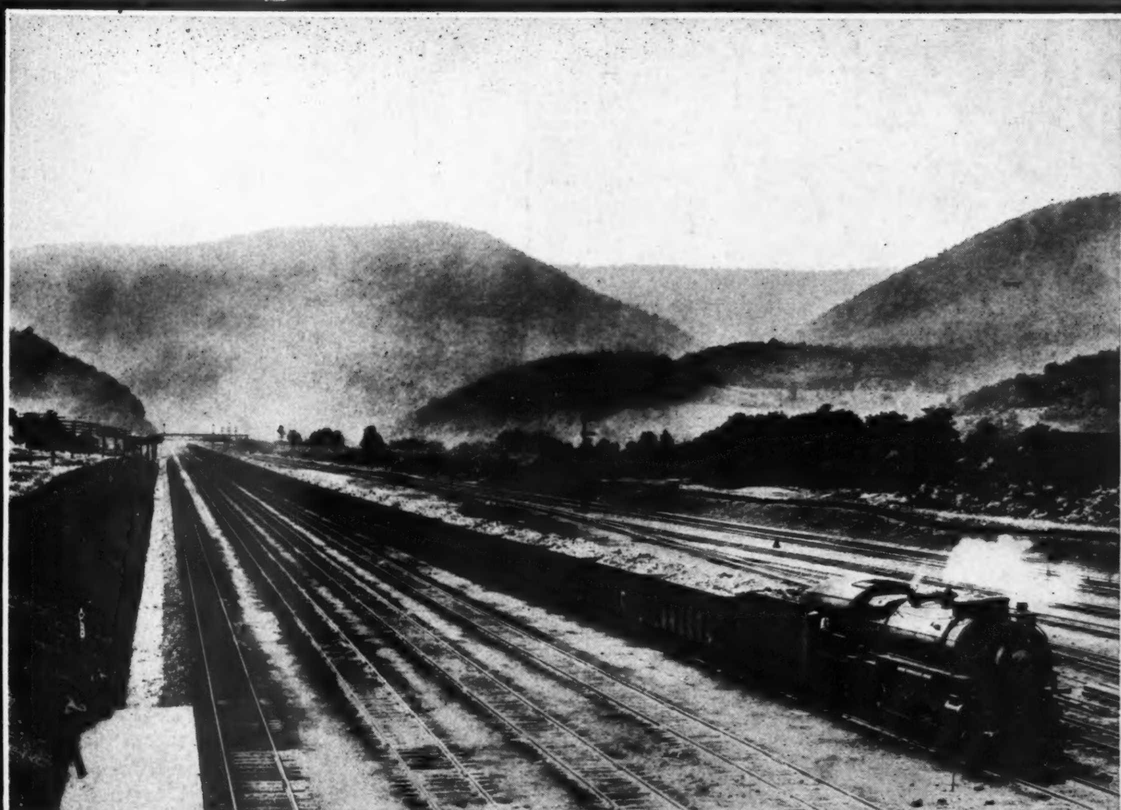

COAL GOES TO MARKET

THE CASE OF COAL
By George H. Ashley

THERMAL CHANGES IN WATER AND STEAM
By Wm. L. DeBaufre

SUBMERGED COMBUSTION
By David Brownlie

OTHER ARTICLES IN THIS ISSUE BY
Charles E. Blais • Fred M. Reiter • B. J. Cross

COMBUSTION

Vol. 1 JUNE 1930 No. 12

CONTENTS

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COMBUSTION

Vol. 1 June, 1930 No. 12

Margins of Improvement in Station Heat-Rates

W. N. BARNARD

IN the last few years we have seen the best central station heat-rates reduced from about 19,000 to below 13,000 B.t.u per kw-hr. and one now wonders what further improvement may be possible in station performance. While it is very hazardous to make predictions in this connection it is at least harmless to attempt a survey of the possibilities. In the boiler room such great advances have already been made in the combustion and heat absorption processes that little margin is left for improving the thermal efficiency there, although many opportunities still remain for bettering the equipment and reducing capital and operating expenditures in this part of the plant; also, under favorable conditions, gains may be effected through recovery of valuable by-products from the raw fuel before its combustion.

For further reduction in station heat-rates one must look mainly to the turbine room, where the recent improvements were effected principally by adopting regenerative feedwater heating, higher steam pressures and temperatures and interstage reheating. Further lowering of turbine rates depends primarily on increasing the throttle pressures and temperatures still more, which places added burden on the boilers and superheaters. Steam generators of commercial types for furnishing steam at pressures around 1400 lb. per sq. in. and at temperatures up to 750 deg. fahr. have been developed with such success that fear of high pressures has been dispelled, and, as a result, many are now engaged in devising new designs and materials which will permit of generating and utilizing the steam at still higher pressure and temperature levels.

These increases will not only effect economies in themselves but may result in the discovery of new ways of utilizing the heat, or permit of applications heretofore not feasible. For example, it seems possible to improve and simplify the methods of multiple interstage resuperheating, to devise cycles which will reduce the sizes and cost of condensers and the low pressure ends of turbines, to greatly broaden industrial applications of bled steam, and to generate considerable by-product power in connection with district heating.

While increasing the steam pressures may improve the thermal efficiencies a little, and also reduce the size of apparatus with possible decrease in investment costs for land, buildings and equipment, it appears that the principal economic gain will be effected through temperature elevation, both directly and through other changes which it makes possible; hence the great effort now being directed to developing high temperature apparatus. At least one manufacturer in the United States is now ready to construct with usual materials superheaters for delivering steam at 850 deg. fahr. With special heat-resistant materials, or possibly by using the cheaper materials with designs which make easy the frequent replacement of parts subjected to greatest punishment, steam temperatures of 1,100 degrees or more may eventually become commercially applicable where local conditions are suitable. Computations seem to show that when this comes about, and progress being made in Europe and in this country indicate that it may be fairly soon, the best heat-rates of central stations may then be lowered another 2000 B.t.u. per kw-hr., and, further, it may be expected that this relatively large thermal gain may be accomplished with little or no addition in plant investment.

Wm. N. Barnard

Professor of Power Engineering,
Cornell University.

EDITORIAL

Coal is King!

BITUMINOUS coal production in this country reached its peak in 1918, since when the annual tonnage figures have been irregular but consistently lower.

Bituminous coal prices are now at the lowest levels since 1917.

Coal is King!

King of a realm that is passing through lean years, but King, nevertheless.

Fully 60 per cent of all our power is produced by coal—over 50 per cent by bituminous coal, alone. Obviosuly, coal is essential to our industrial existence.

Conversely, the confidence and support of industry is essential to the coal producers during these present impoverished years when many coal properties are being operated at a loss.

In his article "The Case of Coal" beginning on page 24 of this issue, Dr. George H. Ashley presents a remarkably clear picture of present conditions in the coal industry. He points to a rift in the clouds beyond which lie greater stability and a brighter future for this basic industry.

Civilization's Contribution to Science

IN commemorating the fiftieth anniversary of the founding of the American Society of Mechanical Engineers, the technical press appropriately devoted much space, during the past month, to reviews of engineering achievements and to pointing out the many ways in which science and engineering have contributed toward advancing civilization and raising our standards of living.

It is interesting to reverse our consideration of the relationship between science and civilization and to reflect upon the extent to which a higher civilization has served to raise the standards of science and engineering.

The greatest change which civilization has brought about in the field of science has been the supplanting of individual effort by group effort as a result of which the individual worker has been able to apply the sum total of existing knowledge to his particular field of effort. With this transition came modern chemistry to prove the fallacy of alchemy, modern physics to end the blind search for that maddening phantom—perpetual motion, and modern astronomy to draw a sharp line of demarcation between itself and astrology. When men learned to work in groups, rationalism crowded out superstition.

While science was teaching civilization how to get larger returns from its efforts, it was learning an equally important lesson itself—the folly of attempting to get something for nothing.

All the forces of Nature seem to be reciprocal in their actions and reactions. Our very existence is a matter of "give and take." The fundamental premises of physics—conservation of matter and conservation of energy—are based on reciprocal relationships and if these beliefs are discarded, as now seems likely, they will in all probability be replaced by new doctrines, which in turn will be reciprocal in their functioning.

Science and Engineering of the old school were individualistic, miserly, secretive and suspicious. Like a pool of water without an outlet, they became stagnant.

Modern Science and Engineering are group interests, co-operative in their functioning and eager to disclose the results of their efforts. They may be likened to the spring of water that keeps fresh by giving away that which it receives.

Engineering has contributed much to the advancement of civilization, but that great principle of reciprocity has been at work and Engineering has in turn benefitted greatly by the civilization in whose building it has played such a conspicuous part.

Why Not Give the Plant a Vacation?

THE Western Electric Company has announced that its Hawthorne plant at Chicago will be closed for two weeks in July to permit its 35,000 employees to take their vacations simultaneously.

Public utilities and many industrial plants must maintain continuous service and obviously such a scheme is not universally applicable. But where conditions permit, there is much merit in the idea of a common vacation period and complete plant shut-down, except for house pumps, fire pumps and similar indispensable equipment.

What an opportunity this plan will give the maintenance gang—ample time to clean boilers; re-gasket leaky joints; inspect, repair and replace equipment; paint stacks and breechings, pack glands and take up bearings.

Why not give the plant a vacation? A respite from routine will give the chief an opportunity to correct many conditions which have had to wait until he could "get a chance."

Greatly Improved Efficiency

Follows Modernizing of Central Power Plant Serving Rhode Island State Institutions

By CHARLES E. BLAIS, Chief Mechanical Engineer, Rhode Island State Institutions, Howard, R. I.

The centralization of steam and power production at the State Institutions, Howard, R. I., began in 1915 when several small plants were replaced by one central plant. In 1928 it was decided to modernize this plant and accordingly four of the horizontal return tubular, hand-fired units were replaced by two stoker-fired, water tube boilers. Extensive tests conducted on the old and new units indicate greatly improved operating results and substantial savings.

A NUMBER of years ago the State of Rhode Island embarked on a centralization program, the purpose of which was to eliminate all isolated power plants serving the State Institutions at Howard, in favor of a large central power plant. The new central source of power, made available in 1915, resulted in the abandonment of the power house serving the State Hospital and also the plant serving the State Infirmary and Women's Reformatory.

The site chosen for the new plant was the logical location, due to its proximity to the New York, New Haven and Hartford Railroad, which would enable the State to advantageously purchase and store large quantities of coal. A large coal bunker, having an aggregate capacity of five thousand gross tons was provided for storage. A spur track laid immediately overhead and running the entire length of the bunker provided excellent facilities for handling at least six cars at one time. The large force formerly employed for trimming was unnecessary with the new system as it was simply a matter of opening up the car door and dropping the coal into the bunker below.

In describing the central power plant, the writer lays no great stress on the power section, the reason being that this plant was designed primarily as a heating plant for heating, laundry and hot water service. The generation of steam was then of prime importance, the generation of electricity being secondary; the current generated was purely a by-product of the steam generation plant, and the prime movers (high-speed reciprocating engines) were installed as an integral part of the piping system, functioning as reducing valves. This arrangement was ideal, the cost of power being practically nil, as all of the exhaust was used up in the low pressure line.

The steam boiler plant consisted of eight hand-fired horizontal return tubular boilers, aggregating 1400 boiler hp. Every precaution was taken to guarantee continuous service to the institutions. A duplicate system of piping and pumps was provided for these units; a large closed water heater, condensate tank, oil separator and coal scale for weighing fuel completed the installation. All in all, this plant was considered at the time a very good lay-out, in fact, one of the best of the institution power plants in New England.

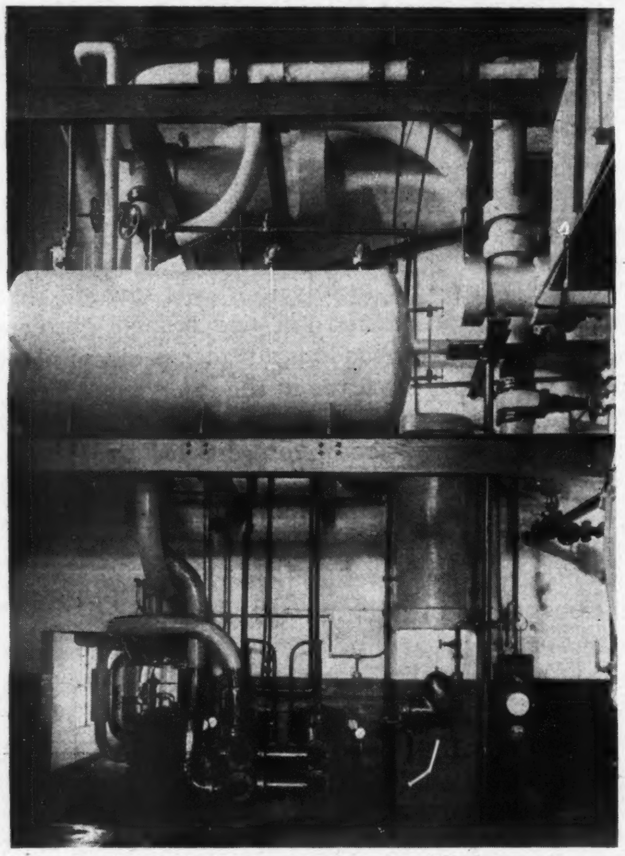
Several years ago, however, it was realized that this plant, installed in 1915, had become obsolete as a result of the tremendous advance in steam plant design which had occurred in the intervening years, and that much better efficiency could be obtained through modernization. Accordingly, it was decided to embark on another program, eliminating certain units constituting the old battery of boilers and replacing them with modern water tube boilers. Authorization was given to prepare plans and specifications for an installation of sufficient capacity to carry the present load. The specifications and plans called for two 500 hp. water tube boilers of the cross drum type, fully equipped with the usual accessories, and including a special tube blower system especially designed for this particular lay-out, non-return valves, steam flow meters, flue gas temperature recorders, steam temperature indicators, draft gages, feed water temperature recorders, and feed water meters of the indicating integrating and recording variety. The specifications also provided for a step compensating regulator, under-feed stokers, coal hoist, underground air duct, with provision made for future expansion of one hundred per cent, a twin set of centrifugal boiler feed pumps, a closed heater, a twin grease extractor, a large blow-off tank of special design, and other accessories.

The numerous items mentioned above constituted the major equipment required for the proposed new installation. The plans and specifications were formally approved by the State Public Welfare Commission and the State Finance Commissioner, with authority to proceed and make installation as covered in the specifications.

The Grinnell Company of Providence was the

successful bidder for the job. No time was lost in making a quick start, following the granting of the contract. Four of the old horizontal return tubular units were quickly dismantled and excavation started for the foundations necessary to support the new units. The construction of this job in all its phases was very unique. For instance, approximately two hundred and fifty yards of solid rock were blasted and removed in order to attain the proper depth for the boiler foundations.

Due to the limited amount of space available, an elevated platform was provided for the forced draft blowers. Outside air ducts carrying combustion air from the fans to the boilers were constructed in connection with an elaborate underground system of air-ducts.



View showing method of supporting closed feed water heater and condensate tank; also partial view of pump room.

An abandoned tunnel located beneath the general store building was utilized for the new pump room. The heater and the condensate tanks were elevated and supported on steel beams, as illustrated on this page. The installation when finished had every appearance of being a marine lay-out.

Personnel

Under the old operating system, the boilers were operated by a mixed crew, part convict and part paid labor. Under the new system, the automatic arrangement of stokers, boilers and pumps eliminates the possibility of inefficient operation, due to the uncertainty resulting from frequent changes in the personnel of the operating crew. A supervisor in charge of a crew of convicts operates the day shift. The middle shift and the last shift are operated by a water tender and a fireman. The entire operating crew employed for operating these units during the heating season, exclusive of the convicts required for trucking the coal from the coal bunkers to the boiler house, constitutes seven men.

Considering the size of this plant and the amount of service rendered, it is felt that the efficiency maintained with such a small operating crew places this station on a par with the best plants in N England.

Evaporative Boiler Tests

The evaporative test conducted at the central power plant, December 21 and 22, 1928, brought to light many interesting features, pertaining to the general operation of the old boilers and principally the ultimate coal cost of producing a thousand pounds of steam from and at 212 deg. fahr. This test was absolutely necessary in order that we might have some method or way of comparing the efficiency of our new boilers with the old installation.

ABSTRACT OF TEST DATA

Tests of boilers Nos. 1, 2, 3, 4, 5 and 9 to determine the cost of coal required to evaporate 1000 lb. of water from and at 212 deg. fahr.

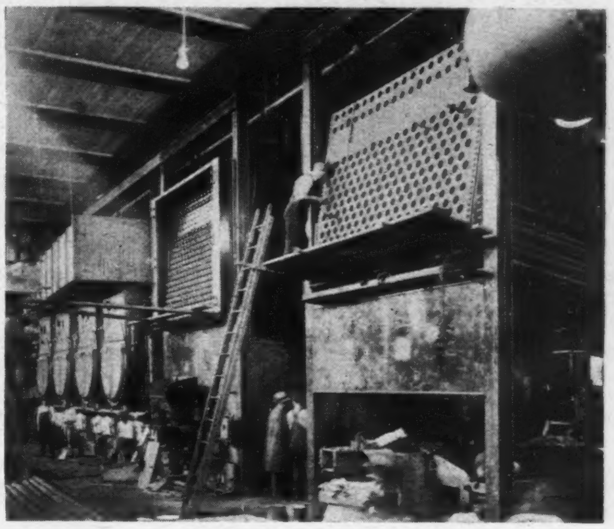
TYPES AND DIMENSIONS	*Old Units*	*New Unit*
1. Number and kind of boilers	Nos. 1, 2, 3, and 4 Wicks H. R. T. No. 9 International H. R. T.	No. 5 Heine Cross Drum Boiler, with Foster Convection Type Superheater.
2. Kind of furnace	Hand fired with flat grates	Type E Stoker
3. Effective grate surface	Nos. 1, 2, 3 and 4 boilers —42 sq. ft. each, No. 9 —45.5 sq. ft., total of 5 units—213.5 sq. ft.	93.75 sq. ft. (10 ft. 5 in. by 9 ft. 0 in.)
4. Effective water heating surface	Nos. 1, 2, 3 and 4 boilers —2000 sq. ft. each, No. 9—2550 sq. ft., total of 5 units—10,550, sq. ft.	5000 sq. ft.
5. Effective superheating surface		912 sq. ft.
6. Ratio of water heating surface to grate surface	Nos. 1, 2, 3 and 4 boilers 47.61:1. No. 9 56.04:1	53.33:1
DATE, DURATION, ETC.		
7. Date	Dec. 21 & 22, 1928	June 5 & 6, 1929
8. Duration	Forty-eight hours	Forty-eight hours
CAPACITY AND ECONOMY		
9. Percentage of rated capacity developed	125.11 per cent	119.43 per cent
10. Equivalent evaporation F. & A. 212 deg. fahr. per lb. of coal as fired	9.518 lb.	11.803 lb.
11. Equivalent evaporation F. & A. 212 deg. fahr. per lb. of dry coal	9.972 lb.	12.06 lb.
EFFICIENCY		
12. Calorific value of 1 lb. of dry coal by analysis	15,082 B.t.u.	14,930 B.t.u.
13. Efficiency of boilers, superheater, furnaces and grates	64.16 per cent	78.38 per cent
COST OF EVAPORATION		
14. Cost of coal per ton of 2240 lb. delivered in boiler house bunker	$5.82	$5.82
15. Cost of coal as fired required for evaporating 1000 lb. of water F. and A. 212 deg. fahr	$0.272	$0.2205

Readings were taken every fifteen minutes for forty-eight consecutive hours, wherever possible, in order that probable errors due to miscalculation or false

averages might be eliminated. The weighing equipment and Venturi Water Meter were checked before the test for accuracy, gage glasses calibrated, blow-off valves sealed tight. In taking the above precautions, we were absolutely sure that our final figures would be as near one hundred per cent accurate as possible. It was very gratifying to note the improvement in our boiler efficiency, due greatly to better firing methods, higher morale and to improved conditions resulting from the installation of the new condensate tank and heater connections, tending to give us an increased average feed water temperature and more uniform conditions.

The evaporative test conducted on June 5 and 6, 1929 was made on the No. 5 Boiler, in order that we might compare the operating efficiency of the new equipment with the old. The results of this test proved the new installation to be very efficient and as a matter of fact, greatly exceeded our expectations regarding the relative merits of these new units. Every precaution was taken on this test to insure accurate readings and the final results compiled from the test data give an excellent comparison.

In comparing the data compiled on both tests, it is only fair to state that on the old boilers, the results attained were achieved by organizing the firing crew and establishing standards which were very rigidly supervised. For a hand-fired installation, the efficiency attained on the first test is considered by the writer as a remarkable showing, due to the fact that our old firing crew was a mixed one, part convict and part paid labor. This fact is mentioned in order to give the new installation full credit in comparing both tests because the relatively high



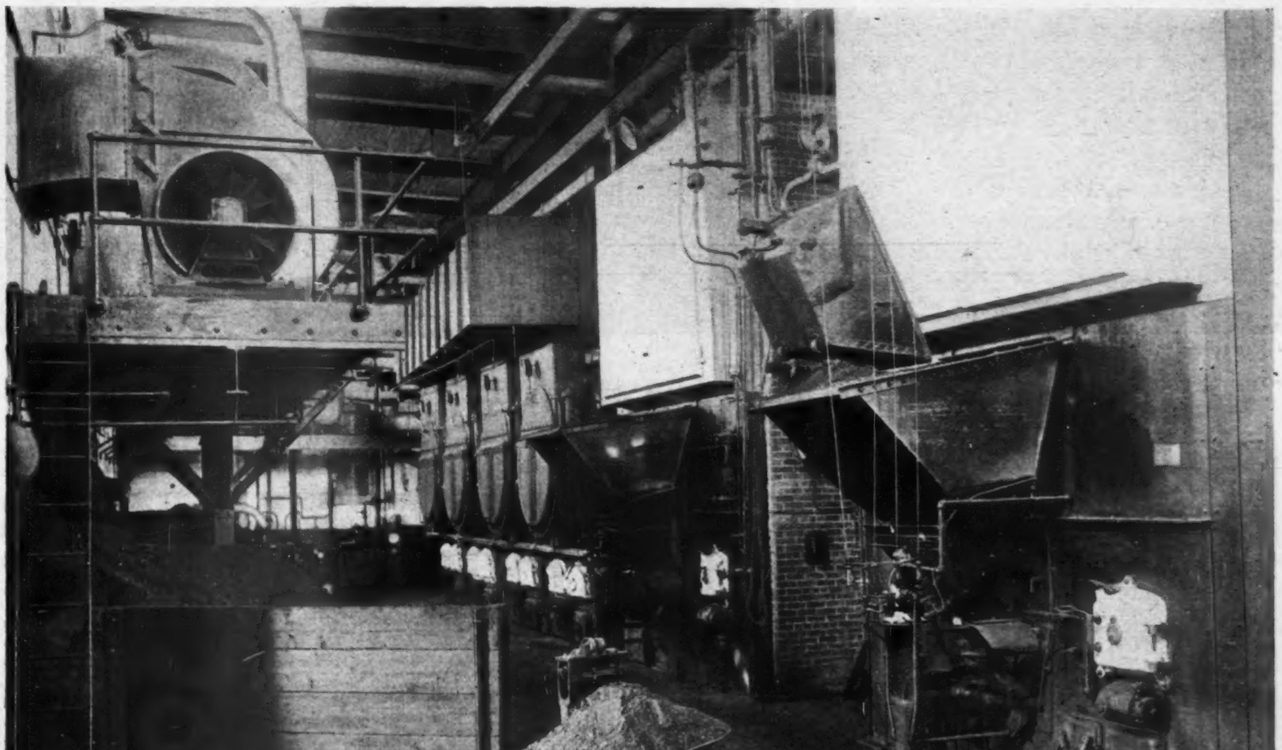
New Boiler units in course of erection.

efficiency attained in the first test could not be considered a positive normal running average.

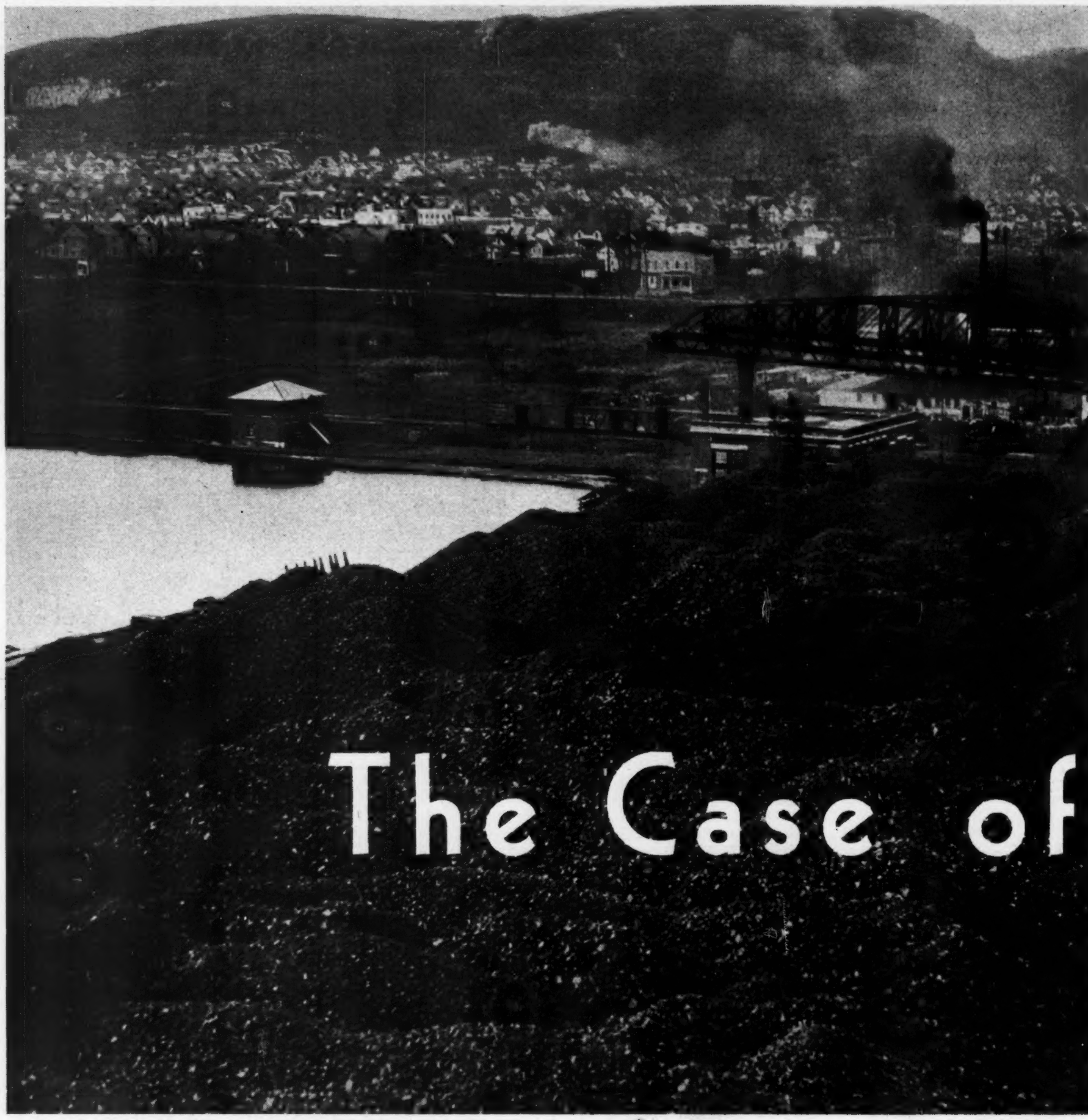
Summary

In analyzing the accompanying data it would be well for the reader to consider certain factors governing some of these items.

(*Continued to page 41*)



View of plant with new units completely installed.



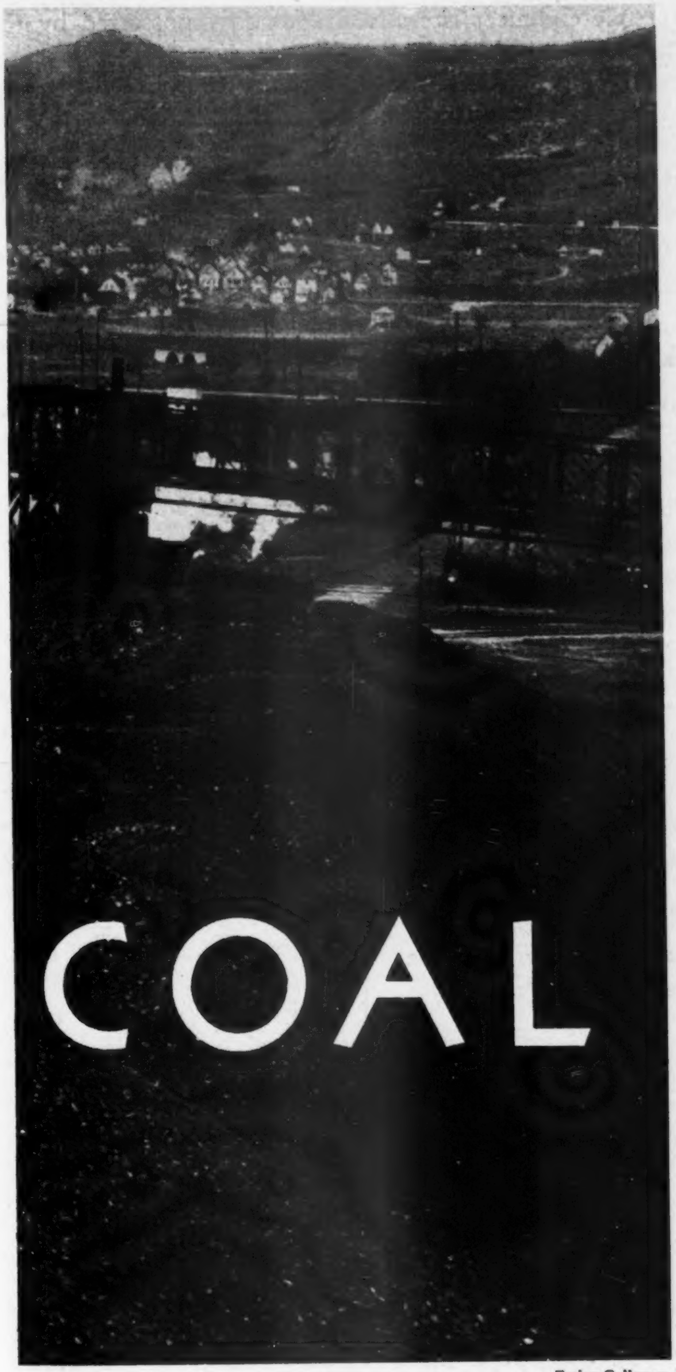
The Case of

By GEORGE H. ASHLEY, State Geologist, State of Pennsylvania

THE kaleidoscopic changes of recent years have led to widespread inquiry as to the present status and future outlook of coal in its relation to other sources of heat and power. The over-production and increasing use of oil for heat and power, the piping of natural gas to Denver, Omaha, and points East, the continued planning and building of huge hydroelectric plants, have obviously greatly modified the coal situation; but just how, to what extent, and their bearing on the future are matters not clearly seen by the average man today.

Up to about one hundred years ago wood and water, animal and human labor, were our principal sources of power and heat. During the past century coal came to be the outstanding source of both heat and power. Seventy years ago oil entered the arena. At first it served mainly for lighting and chemical products. About fifty years ago natural gas came into large commercial use. Water power made little gain until the last quarter of the century.

During the past century the production and use of coal increased in a geometric ratio, on the average doubling each ten years. That rate of increase began to slacken toward the end of the last century, and after 1910 became very irregular, with some gain up to 1918, after which production fell off materially. In 1928 production was down to 569 million tons from a maximum of 678 million tons



Ewing Galloway

IS Coal still King? Is its reign being jeopardized by other fuels which seek to usurp its dominance? Just what is the present situation and how do the various sources of energy compare with respect to —the immediate future—the distant future? Dr. Ashley as State Geologist of Pennsylvania, which produces more coal than any other state in the Union, is eminently qualified to discuss these vitally important questions. He not only discusses them but he makes definite predictions, as to present and future trends. This article presents an up-to-date analysis of the fuel situation from an unquestioned authority.

•

in 1918. Petroleum and natural gas in the eastern States likewise rose during the last century, and then, as supplies became exhausted, production fell off. But meanwhile oil and natural gas had been discovered west of the Mississippi in vast quantities, also in Mexico, and more recently in South America. Production mounted until recently we had reached an output of almost three million barrels a day in the United States alone.

With the beginning of the present century water power, the use of which had been increasing very slowly, donned seven league boots and moved forward rapidly, increasing from 5,356,680 hp. in 1909 to 12,300,000 hp. in 1927.

At the present time, using figures for 1927, the situation is about as follows, expressed as energy or heat units: Coal today supplies over three-fifths of the energy of the United States, domestic oil a little over one-fifth, natural gas and water power each about one-fifteenth. Since these figures were gathered there has been a slight decline in coal and a slight gain in the use of oil and gas, but not sufficient to change this general ratio.

Interest doubtless centers on the future. The future holds two aspects—the immediate future and the distant future. Space will not permit a detailed study of the many and changing factors involved, such as declining immigration, mechanization of coal mines, doubling the efficiency of the use of coal, restraining agreements in the oil industry, and scores of others equally important. In what follows, all of these have been fully considered.

Consider first the immediate future. The production of oil in the Eastern States, which has been on the decline for many years, is apt to hold steady for the next score years, due to new methods of recovering oil formerly left in the rock, and then decline again. Natural gas production in the East has held up for the past few years due to improved care of wells. It seems bound to decline steadily in the future. More efficient use has helped to conserve the supply and to meet a broader market than existed just previously.

In the West both oil and gas supplies appear to be ample to meet increasing markets for several years, certainly for ten years, perhaps more. Then they too will follow the way of the Eastern fields. Importations from South America, already a considerable factor in the problem, are steadily increasing and may postpone the beginning of the decline in the West.

Water power will hold its own and probably increase to double its present output in the next twenty or thirty years, especially as an auxiliary to power from coal.

Coal meanwhile faces lean years. The writer, after a careful analysis of all of the facts, has pre-

dicted a steady decline in the use of coal for at least the next ten years, due to increasing efficiency in its use and growing competition from other sources of energy.

Then the picture will begin to change—sometime between ten and twenty years from now. By that time most of the larger and more easily developed water powers in the East will have been put to work, and the undeveloped powers will be mainly in the far West. Oil and gas production probably will have passed their crest and will have started a slow, steady decline with rapidly mounting prices for gasoline. That should open up the mining of the oil shales of the West and possibly lead to production of oil from coal, as in Germany today.

With the steadily mounting demand for power, (at present 15 per cent a year for gasoline) there will come a shift back to coal, and coal may again look forward to increasing markets and a prosperous industry.

Two questions naturally present themselves. What will the coal industry do in the face of declining markets, and how well can the coal reserves meet future growing markets?

Let no one imagine the coal industry is going to sit supinely by and watch its markets fade away. The coal industry has as good brains as any other. Remember that most of the steel and power companies are also miners of coal, as are Henry Ford and other industrial leaders. To meet the threat of declining markets the coal industry will do two things: reduce the cost of coal by increased mechanization of mines and other efficiencies, and revolutionize the use of coal so as to more and more meet the demand for automatic, smokeless and dustless comfort in house heating, and automatic handling in power production. The coal industry is awake to the fact that in order to sell coal it must meet today's demand for service at a cost below that of other fuels. The chemical treatment of coal to render it dustless is coming on apace. The coal men are spending money freely in developing automatic feeding and control equipment, and dustless, automatic, ash removal. At present, such equipment is too expensive to meet the needs of the average household. In the end it may completely meet the advantages now possessed by the oil burner and at a much lower cost. The development of the gas furnace—now in the offing—will create a new market for coal.

In this struggle to maintain markets, anthracite has some advantages and some disadvantages over bituminous coal. It is already smokeless. But its field is strictly limited. It must continually be dug at greater depths, from thinner beds, with ever increasing physical difficulties to be overcome. It is also carrying a very heavy financial over-burden in the form of high royalties, high land values and taxes which today are all out of proportion to the actual situation—a legacy of the days when an anthracite mine was thought to be a gold mine. The bituminous fields still contain great quantities of thick, level-lying, cheaply minable coal. They are faced however, with a growing demand that their coal be made smokeless before it is used, requiring some form of treatment that in the end will give a better grade of coal but, unless profitable uses can be found for the vast quantity of by-products that would result from such treatment on a large scale, the cost will be higher.

There are three proposals now impending which may materially affect the problem—one favorably, two unfavorably, for the coal producer. Plans are completing for piping natural gas from the southwestern field, as far as Minneapolis, Chicago and way stations, with many side branches. This will replace a large amount of central and eastern coals. On the other hand, recent inventions convert nearly the whole of crude oil into gasoline. As these processes come into use, fuel oil—now a by-product, will go, and its place be taken by coal or gas made from coal. Third, extensive electrification of the railroads is starting. If this cuts the coal needed by two-thirds, or even one-half, it will greatly reduce the market for coal.

As to the future supply of coal in this country—over one-half of the coal of the world, amounting to nearly four trillion tons, is in the United States. Canada comes next with about one-sixth of the whole. Unfortunately a large part of the coal in the United States is of very low rank containing

Dr. Ashley says:

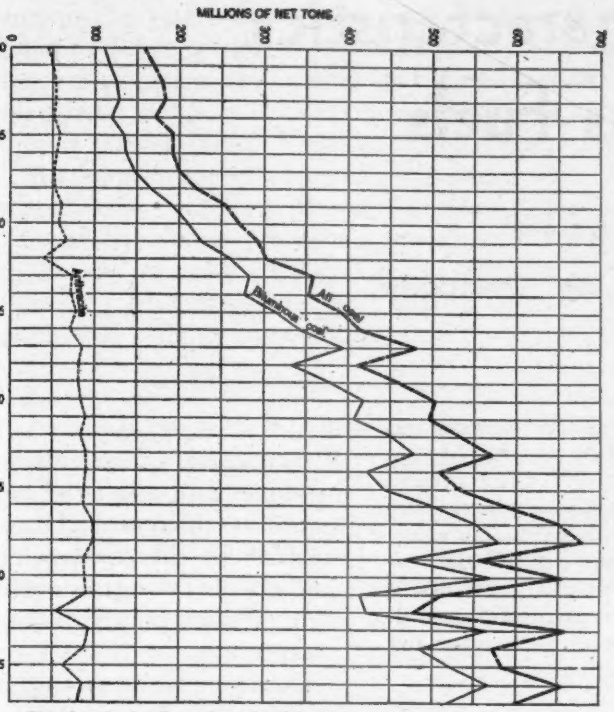
¶ **Coal today supplies over three-fifths of the energy of the United States, domestic oil a little over one-fifth, natural gas and water power about one-fifteenth each.**

¶ **There will be a steady decline in the use of coal for at least the next ten years.**

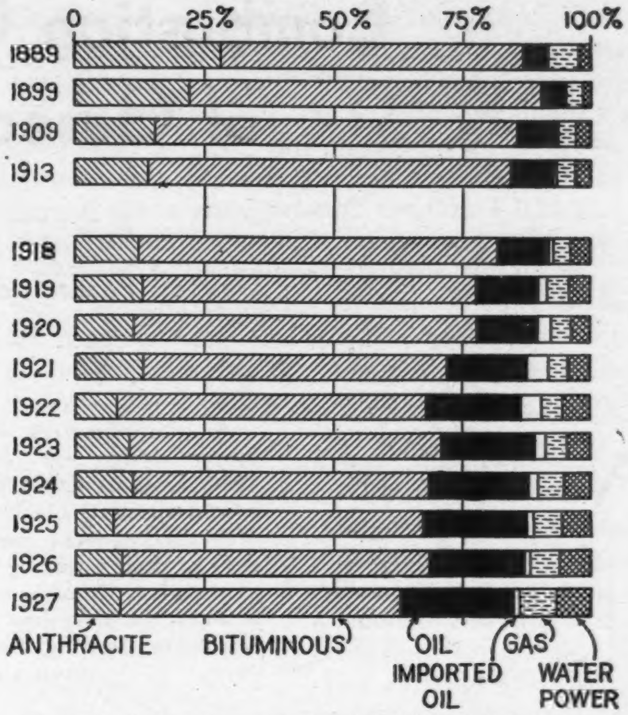
¶ **The picture will begin to change sometime between ten and twenty years from now when there will come a shift back to coal.**

¶ **To meet the threat of declining markets, the coal industry will do two things: reduce the cost of coal by increased mechanization and other efficiencies, and revolutionize the use of coal so as to more and more meet the demand for automatic, smokeless and dustless comfort in house heating and automatic handling in power production.**

¶ **On the basis of the survival of the fittest, Coal is still King in the world of power and gives promise of continuing to be for a long time.**



Production of anthracite bituminous coal, and all coal, 1890-1927.



Per cent of the energy supply of the United States derived from coal, oil, gas, and water power, 1889-1927.

from one-fifth to two-fifths moisture which does not burn and detracts greatly from the value of the coal. On the other hand, this low rank coal seems likely to prove very suitable for the future production of oil, and may, because of this quality and changing use of fuels, acquire a high future value.

It may be safely estimated that with the increasing efficiency in the use of coal, which will doubtless continue and may ultimately double several times over, there should be enough bituminous coal to last at least 300 years; enough anthracite to last 100 years or more; and enough coals below the rank of bituminous to last 1000 years. These figures have absolutely no value except to show that there is coal enough for ourselves and our children's children for several generations. For the discoveries and improvements made in the use of coal in the past warn us that no man can predict the situation 100 years from now, much less 1000 years hence.

Doubling the price of coal during the War set our experts to work and led to doubling the efficiency of our use of coal in large power plants. The mercury engine suggests that a single invention may some day double the power obtained from coal at one stroke. The conversion of coal into gas and its use in internal combustion engines goes a long way toward doing that very thing.

Finally, on the basis of the survival of the fittest—Coal is still King in the world of power, and gives promise of continuing to be for a long time.

Ewing Galloway

The largest coal pile in the world; half a million tons on the long dock at Duluth

Combustion Characteristics of Gaseous Fuels*

By FRED M. REITER

Dayton Power and Light Company

A comprehensive treatise on natural gas burner design was published in the March, 1930, issue of COMBUSTION. The present article discusses the combustion characteristics of various gaseous fuels with particular reference to their effect on burner design. Because of the great variation in these characteristics, it is important that they be given careful consideration in selecting the type of burner for any given application.

A SHORT time ago a plant moved from Dayton, supplied with natural gas, to a city in which manufactured gas was available. Their equipment included a number of vertical high speed heat treating furnaces operating at 2350 deg. fahr. When set up in the latter city, these furnaces operated excellently at heavy loads, giving quick heating and good economy of heat; but when turned down to hold temperature, they persisted in backfiring into the manifold with a pop. This had never occurred in Dayton, and the operators were at a loss.

Some time before this, a local concern purchased a very large furnace from a firm located in a manufactured gas district. Although equipped with the latest type of burners, proportional mixing devices, automatic controls, etc., it was impossible to burn the proper amount of natural gas, with high manifold pressures, until the tunnels or tuyères and the burner openings were properly proportioned. They would blow out.

The causes of such variation in the operation of furnaces in different localities are due to the combustion properties of the gases available at these points of consumption.

Commercial gas fuels, whether distributed to cities or generated within large steel or other establishments, are aggregates or mixtures of certain fundamental gases in varying percentages. These commercial fuels may include natural, coke oven, water, oil, producer, blast furnace, acetylene and other gases. The general composition of the most common of these is tabulated in Table 1.

The properties of a fuel gas depend upon the characteristics of its constituent gases, and the preponderance of certain of these. Natural gas is composed mostly of methane, CH_4, with varying amounts of ethane, C_2H_6. Natural gas used in Dayton has little ethane and over 90 per cent methane. Manufactured gases contain from 30 per cent to 50 per cent hydrogen. Water, producer and blast furnace gases include large

TABLE I

Composition of Commercial Fuel Gases

Gas	Made From	Composition: Per Cent CO	CO^1	CH^2	C^1H^2	C^1H^3	H^1	O^1	N^1	Bt.u. per Cu. Ft. Gas	Vol. Air per Vol. Gas
Natural	....	....	....	92.0	....	3.0	2.5	....	2.5	1,000	9.5
Coal	Bituminous Coal	15.5	2.0	30.5	4.5	3.0	41.0	1.0	2.5	600	5.7
Coke Oven	Bituminous Coal	5.5	2.0	34.5	2.5	...	53.5	...	2.5	550	5.3
Water Gas:											
Blue	Coke	43.0	4.5	2.0	....	...	46.5	1.0	3.0	300	2.5
Carburetted	Coke-Oil	30.0	3.5	10.0	12.5	3.0	37.5	1.0	2.5	580	5.2
Producer Gas:											
Anthracite	Anthracite	22.0	4.5	2.5	....	...	2.5	...	68.5	117	1.0
Bituminous	Bituminous	25.0	6.0	1.0	....	...	12.0	1.0	55.0	130	1.8
Oil	Oil	35.0	6.5	10.0	19.5	1.0	1.0	1.0	57.5	450	4.2
Blast Furnace	Coke	25.0	13.0	1.0	....	...	3.0	1.0	57.0	100	1.0
Oil Gas	Oil	0.5	1.5	17.0	46.0	...	31.5	...	5.0	650	6.0
Acetylene	Carbide	95% acetylene (C_2H_2)						1.0	4.0	1,470	12.5

* REPRINTED FROM INDUSTRIAL GAS, APRIL 1930

percentages of carbon monoxide. The important combustion characteristics of the constituent gases are found in Table 2. By "velocity of flame" is meant the rate at which combustion will travel through a mixture of the gas with the proper amount of air at normal temperatures. The "kindling temperature" is the temperature at which the gas mixed with the proper amount of air will ignite or burn. The "inflammability limits" represent the range of mixture of the gas with air that will burn. The "volumes of inert gases per volume of combustible gas" are those that will prevent the mixture from burning.

Effects of Properties of Gases

A study of these properties of fuel gases will readily explain their effects upon their application to burners and furnaces. The combustion characteristics given are based upon definite experimental conditions. They would have different values under other conditions. At increased temperatures the flame velocities would be very much higher, as is found in furnaces that are up to temperature compared to starting up cold. However, the various gases would be affected similarly so that the figures given would be relative under most conditions.

The maximum flame velocity occurs when the gas is mixed with approximately the theoretically correct amount of air required for perfect combustion, or perhaps very slightly oxidizing. The chart (Fig. 1) gives the rate of flame propagation of the most common gases with varying amounts of air. The maximum velocities, the topmost points of the curves, occur at close to the requisite amount of air for perfect combustion.

Those who have had the experience of adjusting burners for best operation can attest to these findings, for a good, sharp flame is obtained at the proper mixture, which lengthens out or goes out entirely when the mixture is varied either way. A slight excess of air may give too short a flame.

The lower the percentage of combustible gas in an inflammable mixture, the greater the percentage of excess oxygen required to propagate the flame. This may be encountered with producer and blast furnace gases or where recirculation of the products of combustion occurs. For example, for carbon monoxide, as the presence of carbon dioxide in the mixture increases, or the precentage of CO becomes less, the proportion of oxygen necessary for continuing the flame must be increased. At 16.5 per cent CO with 40.3 per cent CO_2, 8.3 per cent of oxygen must be present. From 13.3 per cent CO, the oxygen required is 18.1 per cent. This accounts for a seeming incompatability between the lower inflammability limits and the calculation of oxygen present for the volumes of inerts that will extinguish the flames. This calculation seems to indicate sufficient oxygen in the mixture to chemically burn the combustible gas, but the excess of oxygen required for the lower limits is not available, and the combustion is not sustained.

To visualize the action of a gas burner, we can imagine a long glass tube containing a mixture of methane and air in correct proportions. If we light it at one end the flame will travel toward the other end at a rate of 2.3 ft. per second, assuming certain conditions without violent explosion. Were we to open a valve at the end of the tube and permit the flow of the mixture through the tube at the rate of 2.3 ft. per second and light it, the flame would hover stationary at the point of ignition, due to the fact that the velocity of the mixture flowing through the tube just equals the speed of the flame tending to travel back toward the inlet. If the mixture flow were increased to say 3.3 feet per second, the flame

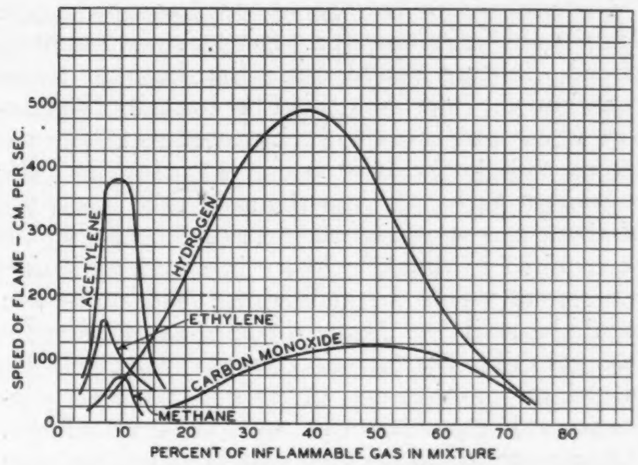


Fig. 1—Rate of Flame Propagation of the most common gases with varying amounts of air.

would travel along the tube in the direction of flow at the rate of 1 foot per second, the difference between the speed of the gas mixture and the flame. In other words, it would blow out.

Similarly, if the flow were dimished to 1.0 foot per second, the flame would travel back into the supply pipe at the speed of 1.3 feet per second. In plain language, it would flash back into the burner. Such a burner would be unstable, and with the impossibility of maintaining a precisely constant flow in practice, it would be worthless.

If we now place a restriction or orifice in the tube of one-half the area of the tube, the velocity of the mixture through the orifice would be doubled. For a normal flow of 2.3 feet per second in the tube (4.6 feet per second through the orifice), the flame would "blow away" from the orifice until the expansion of the cone from the orifice reached the full area of the tube with a restored velocity of 2.3 feet per second, at which point the flame would hold. Under such conditions we would be enabled to turn down the mixture to one-half the flow and maintain the flame. This orifice, called a "burner nozzle," permits a turn-down of 50 per cent without "flash-back."

Unless the length of the tube were maintained after the "nozzle" until the flow was restored to normal, the flame would blow out, for, after mixing

with the atmosphere beyond the nozzle, dilution would render the new mixture non-inflammable. Hence, in practice, tuyere blocks or tunnels are placed after the burner nozzle designed for proper length and diameter to reduce the velocity and confine the mixture to its proper composition. These tuyeres also serve to reduce the velocity of the outside skin of the jet by friction as well as to produce a turbulence, which assist, in the ignition of the mixture. As these tuyere blocks become incandescent or hot, they heat the mixture and increase the flame speed characteristics of the gas so that quick ignition occurs.

Substituting Hydrogen for Methane

If we substitute hydrogen for methane in the tube described where a flow of 2.3 feet per second is maintained, lighting would cause the flame to travel back into the inlet at 13.7 feet per second. The mixture flow would have to be increased to 16 feet per second to hold the flame at a given point. In order to prevent flash back into the same tube, an orifice of about 14 per cent of the area of the tube would be required so that a velocity in excess of 16 feet per second would be maintained. No turn-down would be available. Hence the presence of hydrogen in a gas mixture greatly increases its flame velocity in quicker ignition and better sustenance of combustion at higher mixture pressures and greater flows.

Returning to our original two furnaces that were shifted into districts having different types of gases available than those for which they were designed, the principles discussed show the reasons for their temporary failure. Dayton is supplied with a gas consisting almost entirely of methane with practically no hydrogen, so that a very low combustion velocity results. Manufactured gas, however, with a high hydrogen content, has a comparatively high flame speed. The furnace moved from Dayton, with burners designed for low velocity gases, when fired with manufactured gas, needed but a reduction in burner port area to produce a more rapid mixture flow for the same heat input into the furnace.

The second furnace, moved into Dayton, needed a reduction in gas mixture velocity or longer tunnels or tuyeres with proper flare to encase the conical jet emerging from the burner nozzle. Since a reduction in mixture flow would lower the mixture pressure and possible turn-down, a change in the tuyeres was more advisable. This change gave perfect operation of the furnace with ample range in capacity. It could be turned on full when cold, with perfect ignition.

The examples have been given merely to illustrate the great variation in the combustion characteristics of gases. The flame velocities given in the tables or curves cannot be used for the actual design of burners since so many variables are involved. The general effects of some of these agencies are as follows:

1. *Turbulence:* The rapidity of ignition increases with the turbulence of the flow of the gas mixture. Actually, the turbulence of the mixture probably decreases the linear velocity of the gases, particularly of the central core of the stream, permitting the flame to hold more readily. The character of the burner flame will show this turbulence in the flare or size of the flame. This principle is used frequently in furnace design, especially with fuel oil and pulverized coal, in the use of flame breakers or spreaders.
2. *Temperature:* The flame velocity increases rapidly with the increase in temperature of the fuel mixture. Gas burners that have a tendency to blow out when cold operate smoothly when the furnace is hot. They may even flash back if the burner gets hot. In the ignition of fuel oil, auxiliary heat in the form of gas pilots, oily rags, wood, etc., are used until the burner area becomes heated.
3. *Diluents:* The presence of other gases affect the combustion of gas mixtures. It is claimed that the presence of a small amount of water vapor enhances, while inerts, such as nitrogen and carbon dioxide, reduce the flame speed. Steam atomization of fuel oil in large steel mill furnaces seems to have this advantage. The addition of

(*Continued to page 46*)

TABLE 2

Combustion Characteristics of Gases

Gas	Symbol	Kindling temperature, deg. fahr.	Velocity[1] of flame, ft. per sec.	inflammability limits[2] mixed with air. per cent of gas Lower	Upper	Volumes of inert gases[3] that will extinguish flames, per vol. gas Nitrogen	CO_2
Hydrogen	H_2	1,130	16.1	4%	74%	16.55	10.20
Carbon monoxide	CO	925	3.9	12	73	4.12	2.16
Methane	CH_4	1,202	2.3	5	14	6.00	3.20
Ethane	C_2H_6	1,000	....	3	12.5		
Ethylene	C_2H_4	1,022	5.2	3	34		
Acetylene	C_2H_2	900	9.2	2.5	80		

[1] "Fuel in Science & Practice," Payman & Wheeler.
[2] Bureau of Mines, Bulletin 297.
[3] Jones & Perrott, Bureau of Mines, Indus. & Eng. Chem., Vol. 19, No. 9.

Thermal Changes in Water and Steam*

By WM. L. DE BAUFRE, International Combustion Engineering Corporation, New York

In this fifth article in the series by Mr. DeBaufre, the methods of calculating thermal changes in water and steam are described with reference to the heating of water, the generation of steam and the expansion of steam where flow of the fluid is not involved. In discussing the method of determining the heat added to water between two temperatures, the author points out that the customery practice of subtracting the total heats as given in tables of thermal properties of water is sufficiently accurate for most practical purposes, although it is theoretically incorrect. In the generation of steam it is theoretically correct to subtract the total heats to get the heat added, but in the expansion of steam, it is not only theoretically incorrect, but practically not sufficiently accurate. The correct methods of calculating the heat added during expansion and during constant volume changes are presented herein.

CHANGES in temperature and in volume of water and of steam are accompanied by other thermal changes, the magnitudes of which may be calculated by means of tables of the thermal properties of this substance, such as those prepared by J. H. Keenan and recently published by the American Society of Mechanical Engineers. The methods of calculating such thermal changes will be explained in the present article for the heating of water, for the generation of steam and for the expansion of steam where flow of the fluid is not involved. Thermal changes in fluids during flow will be treated in another article.

The Heating of Water

For many engineering calculations, it is sufficiently accurate to take the specific heat of water as unity, particularly if the temperatures involved are less than the boiling point under atmospheric pressure, 212 fahr. Above the boiling point, however, the specific heat increases rapidly with the temperature as shown by Fig. 1, becoming 5 per cent greater than at atmospheric temperatures around 350 fahr. and 50 per cent greater around 600 fahr. For accurate scientific calculations at room temperatures and for reasonably accurate engineering calculations at higher temperatures, it is therefore necessary to take into account the variation of the specific heat of water with the temperature.

Instead of utilizing the specific heat to get the heat added to water, it is customary to subtract the "total heats" at the initial and final temperatures given in tables of the thermal properties of water. As explained in a previous article, "total heat" is defined by the mathematical expression

$$h = u - u_0 + A\,p\,v$$

where u_0 is the internal energy at some reference temperature, u is the internal energy at the temperature in question, p is the pressure to which the fluid is subjected, v is the volume of the fluid and A is the reciprocal of the mechanical equivalent of heat if the total heat h is given in heat units. Subtracting the total heats at the initial and final temperatures, we have

$$\Delta h = h_2 - h_1 = u_2 - u_1 + Ap_2\,v_2 - A\,p_1\,v_1$$

Now, from the first law of thermodynamics given in a previous article, the heat actually added between the initial and final temperatures is

$$\Delta q = u_2 - u_1 + A\int_{v_1}^{v_2} p\,dv$$

It is evident that the heat added Δq is equal to the difference Δh of the "total heats" only in the case where the pressure p during the heating is constant so that $p = p_1 = p_2$.

In tables of the thermal properties of water, the total heat given at each temperature corresponds to a pressure on the water equal to that of saturated steam at the temperature in question. The pressures are not the same at different temperatures. Accordingly, there is an error in substracting the total heats to get the heat added between any two temperatures. The error is so small, however, that it is generally negligible, as will be shown by the two following examples.

Consider the heating of water from 60 to 200 fahr. From Keenan's Steam Tables, we have

Total heat at 60 fahr.,

$$h_{60} = 28.05 \text{ B.t.u. per lb.}$$
$$= (u_{60} - u_{32}) + A\,p_{60}\,v_{60}$$
$$p_{60} = 0.2561 \times 144 = 36.9 \text{ lb. per sq. ft.}$$
$$v_{60} = 0.01603 \text{ cu. ft. per lb.}$$
$$A\,p_{60}\,v_{60} = \frac{36.9 \times 0.01603}{778.6} = 0.00076 \text{ B.t.u. per lb.}$$

Total heat at 200 fahr.,

$$h_{200} = 167.94 \text{ B.t.u. per lb.}$$
$$= (u_{200} - u_{32}) + A\,p_{200}\,v_{200}$$
$$p_{200} = 11.525 \times 144 = 1660 \text{ lb. per sq. ft.}$$
$$v_{200} = 0.01663 \text{ cu. ft. per lb.}$$
$$A\,p_{200}\,v_{200} = \frac{1660 \times 0.01663}{778.6} = 0.0355 \text{ B.t.u. per lb.}$$

Subtracting the two total heats, we have

$$h_{200} - h_{60} = (u_{200} - u_{32}) + 0.0355 \text{ B.t.u.} - (u_{60} - u_{32}) - 0.00076 \text{ B.t.u.}$$
$$= (u_{200} - u_{60}) + 0.0347 \text{ B.t.u.}$$

The heat added between 60 and 200 fahr. is actually equal to

$$\Delta q = (u_{200} - u_{60}) + A \int p\, dv$$

$$= (u_{200} - u_{60}) + A\ p_m\ (v_{200} - v_{60})$$

where p_m is the mean pressure between 60 and 200 fahr. If p_m is constant and equal to the standard atmospheric pressure of 14.696 lb. per sq. in., then $p_m = 144 \times 14.696 = 2116$ lb. per sq. ft. and

$$A\ p_m\ (v_{200} - v_{60}) = \frac{2116\ (0.01663 - 0.01603)}{778.6}$$

$$= 0.0016 \text{ B.t.u. per lb.}$$

Thus, the error in substracting the "total heats" is $0.0347 - 0.0016 = 0.033$ B.t.u. per lb. The actual error is very slightly greater than this due to the volume of water under atmospheric pressure being somewhat less than under its saturation pressure at 60 fahr. Also, there may be a very small difference

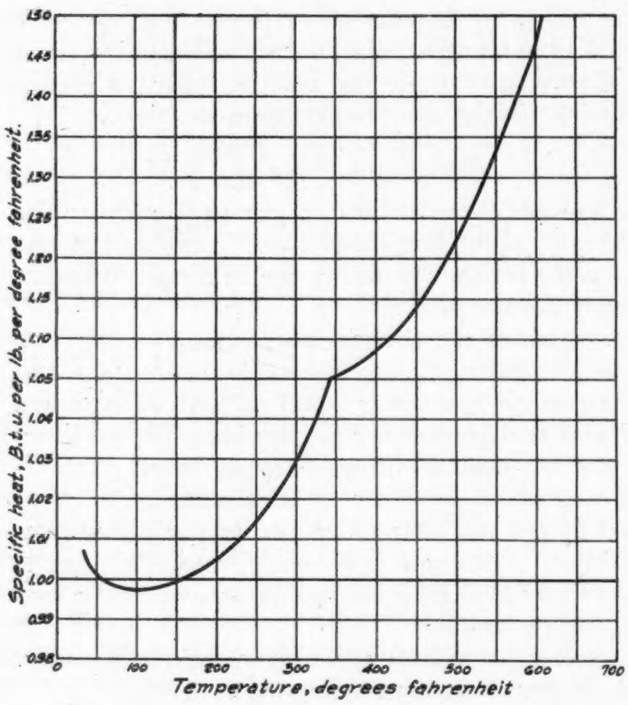


Fig. 1—Specific heat of water calculated from total heats given in Keenan's Steam Tables.

in the internal energy of water at 60 fahr. under saturation pressure and the internal energy under atmospheric pressure. The difference in the "total heats" at 60 and 200 fahr. is $167.94 - 28.05 = 139.89$ B.t.u. per lb. The error in the external work thus amounts only to about $0.033/139.87 = 0.025$ per cent, which is within the experimental error of measurement of the thermal properties of water. At low temperatures and pressures, therefore, no attention need be paid to the pressure-volume relation in calculating the heat added to or abstracted from water to change its temperature.

At high pressures and temperatures, the error may amount to about one per cent of the heat added. Thus, let water be heated from 200 to 600 fahr. under the saturation pressure corresponding to the latter temperature, namely, 1544.6 lb. per sq. in. absolute. Then,

Total heat at 600 fahr.,

$$h_{600} = 623.2 \text{ B.t.u. per lb.}$$

$$= (u_{600} - u_{32}) + A\ p_{600}\ v_{600}$$

$$p_{600} = 1544.6 \times 144 = 222{,}422 \text{ lb. per sq. ft.}$$

$$v_{600} = 0.0241 \text{ cu. ft. per lb.}$$

$$A\ p_{600}\ v_{600} = \frac{222{,}422 \times 0.0241}{778.6} = 6.88 \text{ B.t.u. per lb.}$$

Subtracting the total heats at 200 and 600 fahr., we have

$$h_{600} - h_{200} = (u_{600} - u_{32}) + 6.88 \text{ B.t.u.} - (u_{200} - u_{32}) - 0.0355 \text{ B.t.u.}$$

$$= (u_{600} - u_{200}) + 6.84 \text{ B.t.u.}$$

The heat actually added between 200 and 600 fahr. is

$$\Delta q = (u_{600} - u_{200}) + A\ p_m\ (v_{600} - v_{200})$$

in which $p_m = 1544.6 \times 144 = 222{,}422$ lb. per sq. ft.

$$A\ p_m\ (v_{600} - v_{200}) = \frac{222{,}422\ (0.0241 - 0.0166)}{778.6}$$

$$= 2.14 \text{ B.t.u. per lb.}$$

The error in subtracting the "total heats" is $6.84 - 2.14 = 4.70$ B.t.u. per lb. As compared with the difference in the "total heats" of $623.2 - 167.94 = 455.3$ B.t.u. per lb., the error is $4.70/455.3 = 1.03$ per cent.

The significance of the above error may be explained by the aid of the pressure-volume diagram of Fig. 2. The difference of the "total heats" involves the difference in the two rectangles 4270 and 5160. The external work during heating from 200 to 600 fahr. is represented by the area 3276. The point 3 has been taken to represent the same volume as point 1, no correction having been applied for compressibility of the water because this amounts to about 0.4 per cent only under 1544.6 lb. per sq. in. pressure. The error in taking the difference of the "total heats" as the heat actually added is represented by the area 4315. This corresponds approximately to the work done by the feed pump in forcing the water into the heater against 1544.6 lb. per sq. in. absolute pressure, the original pressure on the water being atmospheric.

The temperature-entropy diagram for heating water from 200 to 600 fahr. is shown in Fig. 3. The entropy values were taken from Keenan's Steam Tables, which means that the area under curve 12 represents the heat added to water while under the varying pressure of saturated steam corresponding at each point to the temperature of the water as it changes from 200 to 600 fahr. The heat added under these conditions is less than that added under the constant pressure of saturated steam corresponding to 600 fahr. by the difference between the areas 3276 and 1276 of Fig. 2. The latter area is approximately given by

$$\frac{1660 + 222{,}422}{2} \times \frac{0.0241 - 0.0166}{778.6} = 1.08 \text{ B.t.u. per lb}$$

The error is therefore $2.14 - 1.08 = 1.06$ B.t.u. per lb., which is less than one-quarter of one per cent and is too

small to show on the temperature entropy diagram.

It will also be noticed that the values of Apv are small, particularly at low temperatures, relative to the values of the total heat h. Hence differences in total heats may be taken approximately as changes in the internal energy of water between the temperatures under consideration.

The Generation of Steam

Let us consider the case in which feed water at 200 fahr. is forced into a boiler where it is evaporated under 300 lb. per sq. in. absolute pressure and then superheated to 700 fahr.

After being forced into the boiler, the water is first heated to the saturation temperature of 417.33 fahr. before it is evaporated into steam. From Keenan's Steam Tables, the total heats of water at 200 and 417.5 fahr. are 167.94 and 393.9 B.t.u. per lb. respectively. Subtracting these two quantities, we find the heat added to the water before evaporation is 226.0 B.t.u. per lb. The external work corresponding to the expansion between the initial and final volumes of the water of 0.01663 and 0.0189 cu. ft. per lb., is 144 x 300 x (0.0189—0.0166) / 778.6=0.13 B.t.u. per lb. This shows that in heating water, external work accounts for but a very small fraction of the heat added which is mostly internal kinetic energy of the molecules, or sensible heat. The error due to taking the heat

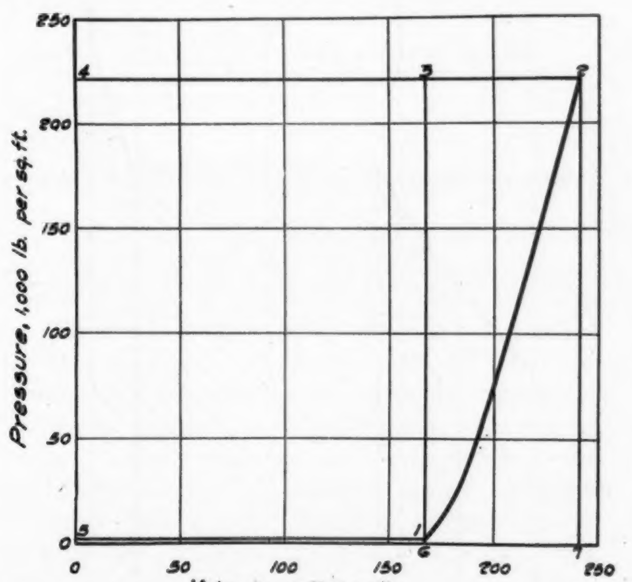


Fig. 2—Pressure-volume diagram for heating water from 200 to 600 fahr.

added to water under constant pressure as equal to the difference of the total heats, will be neglected as is customary.

In evaporating the water into steam under 300 lb. per sq. in. absolute pressure, the total heat is changed from 393.9 B.t.u. per lb. for liquid to 1202.4 B.t.u. per lb. for dry saturated vapor. The difference between these two quantities, namely, 808.5 B.t.u. per lb., is the correct value of the heat added during evaporation because evaporation occurs under constant pressure. This quantity is the latent heat of the steam, no temperature change having occurred during evaporation. In expanding from water having a volume of 0.0189 cu. ft. per lb. to steam having a volume of 1.5414 cu. ft. per lb., the external work done, or the external latent heat, is 144 x 300 x (1.5414—0.0189) / 778.6=84.5 B.t.u. per lb., which passes out of the steam to the surroundings. The internal latent heat is 808.5—84.5=724.0 B.t.u. per

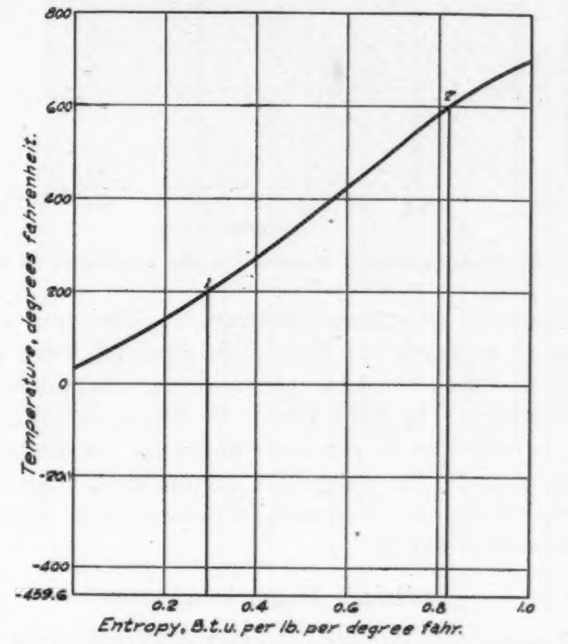


Fig. 3—Temperature-entropy diagram for heating water from 200 to 600 fahr.

lb., which remains in the steam and represents the increase in potential energy of the molecules in order to change the water into steam.

In superheating the steam from 417.33 to 700 fahr., the total heat is changed from 1202.4 to 1367.8 B.t.u. per lb. The difference of 165.4 B.t.u. per lb. is the heat added in the superheater. The volume changes during superheating from 1.5414 to 2.224 cu. ft. per lb., the corresponding external work being 144 x 300 x (2.224—1.541) / 778.6=37.9 B.t.u. per lb. The difference, 165.4—37.9=127.5 B.t.u. per lb., is the increase in internal energy of the steam during superheating. Since both temperature and volume of the steam change during superheating, this increase in internal energy is composed of both kinetic and potential energy of the molecules. Superheating of steam generally occurs while the steam is flowing through tubes so that the phenomena of steady flow are involved as will be discussed in a later article.

The work done and the heat added in generating steam may be represented on the pressure-volume and temperature-entropy diagrams, respectively. Thus in figures 4 and 5, point 1 represents the feed water, point 2 represents the water when heated to the temperature of evaporation, point 3 represents the dry saturated steam generated and point 4 represents

the superheated steam. The area under line 12 in Fig. 4 represents the external work done during heating of the water, but the external work is practically zero to the scale of the figure. The area under line 12 in Fig. 5 represents the heat added to the water

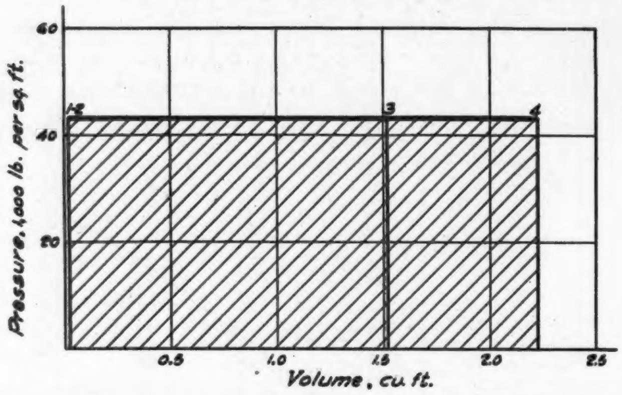


Fig. 4—Pressure volume diagram for the generation of steam.

to raise it to steam temperature. The area under line 23 represents in Fig. 4 the external work done and in Fig. 5 the heat added during evaporation of the water. The same quantities during superheating are represented by the areas under 34. In comparing Fig. 4 and 5, it should be remembered that equal areas on the two diagrams do not represent the same amounts of energy.

Adiabatic Expansion of Steam

Early steam pumping engines admitted steam during the full stroke of the piston. The work done by the steam upon the piston was therefore equal to the external latent heat of the steam as calculated in a preceding paragraph. Watt conceived the idea of cutting off the supply of steam to the cylinder before the piston reached the end of its stroke, thereby permitting the steam to expand with drop in pressure and do work upon the piston at the expense of the internal energy in the steam. Expansion of steam and other fluids without addition or abstraction of heat was called *adiabatic* expansion by Rankine from a Greek word meaning "not passing through" because such expansion can occur only in cylinders with walls impervious to heat.

Now the temperature-entropy diagram represents the heat added to or abstracted from a substance as its temperature and entropy change. Only a vertical line on this diagram can represent a thermal change in which no heat is added or abstracted. Hence the entropy must be constant during adiabatic expansion, a fact which is also shown by the mathematical relation between heat and entropy, namely,

$$dq = T\ ds$$

where dq is the heat added at absolute temperature T with a corresponding entropy change ds. We are of course considering conditions above the absolute zero of temperature where T is not zero.

Figure 6 is a temperature-entropy diagram for steam on which lines have been drawn to represent constant dryness fractions within the wet region and to represent constant degrees of superheat in the superheated region. Starting from point B on the saturated vapor line, it is seen that adiabatic expansion to a lower pressure results in a partial condensation of the steam, as indicated by point F relative to the lines of constant quality. Starting in the superheated region at point C, adiabatic expansion causes a reduction in the degree of superheat, and if the expansion be carried sufficiently far, the steam will reach the saturated condition at point D and then partly condense as indicated by point E in the wet region. On the other hand, adiabatic expansion of water from point A on the saturated liquid line results in evaporation of a portion of the water, as indicated by the position of point E relative to the lines of constant quality. Given the initial pressure and quality of steam, the quality after adiabatic expansion to a lower pressure may be determined on the basis of constant entropy. Other thermal changes can then be calculated as will be illustrated by a numerical example.

Let the initial condition of the steam be dry and saturated under 200 lb. per sq. in. absolute pressure as represented by point B in Fig. 6. Then the initial temperature of the steam will be 381.82 fahr., its volume will be 2.285 cu. ft. per lb., its total heat

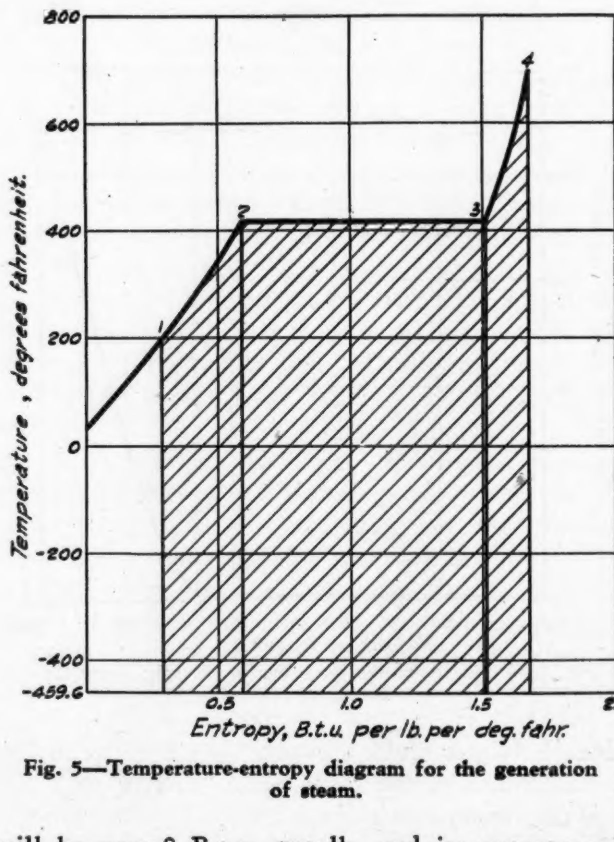


Fig. 5—Temperature-entropy diagram for the generation of steam.

will be 1197.8 B.t.u. per lb. and its entropy will be 1.5450 B.t.u. per lb. per degree fahr. absolute, all taken from Keenan's Steam Tables. After adiabatic expansion to atmospheric pressure, the steam will be wet as indicated by point F in Fig. 6. The dryness fraction x may be calculated from the fact

that the entropy after expansion is the same as the initial value of 1.5450. From the Steam Tables, we find the entropy of saturated water under atmospheric pressure to be 0.3119 and the entropy of evaporation to be 1.4446. Hence,

$$0.3119 + 1.4446\,x = 1.5450$$

Whence, $x = 0.8536$ dryness fraction

and $1 - x = 0.1464$ moisture fraction

The volume of the steam after expansion is

$0.01670 \times 0.1464 + 26.82 \times 0.8536 = 0.002 + 22.89 = 22.89$ cu. ft. per lb. where 0.01670 cu. ft. per lb. is the specific volume of water and 26.82 cu. ft. per lb. is the specific volume of dry saturated steam under atmospheric pressure. The total heat of the steam after expansion is

$180.0 + 970.2 \times 0.8536 = 1008.2$ B.t.u. per lb.,

where 180.0 B.t.u. per lb. is the total heat of saturated water and 970.2 B.t.u. per lb. is the latent heat of evaporation under atmospheric pressure. The change in total heat from 1197.8 to 1008.2 B.t.u. per lb. has a significance which will be explained in a future article. However, it is not the heat abstracted from the steam during expansion because this is zero. Neither is it the work done during expansion, which must be equal to the change in internal energy and will now be calculated.

The internal energy of steam is not given in Keenan's Steam Tables; hence, it is necessary to calculate it by subtracting Apv from the tabulated value of the total heat. Under the initial conditions,

$$Apv = \frac{144 \times 200 \times 2.285}{778.6} = 84.5 \text{ B.t.u. per lb.}$$

Hence, $1197.8 - 84.5 = 1113.3$ B.t.u. per lb. initial internal energy. For the final conditions,

$$Apv = \frac{144 \times 14.696 \times 22.89}{778.6} = 62.2 \text{ B.t.u. per lb.}$$

Hence, $1008.2 - 62.2 = 946.0$ B.t.u. per lb. final internal energy. The change in internal energy during adiabatic expansion is $1113.3 - 946.0 = 167.3$ B.t.u. per lb. Hence the work done during expansion is $167.3 \times 778.6 = 130{,}260$ ft. lb. per lb. of steam. This is the work done on the piston of an engine during expansion only and does not include the work done during admission of steam into the cylinder, which is the external latent heat of the steam admitted. Neither is the work done by the piston in exhausting the steam from the cylinder considered. The net work done on the piston will be discussed in a later article which will deal with the performance of the engine as a whole.

Instead of determining the work done during adiabatic expansion of steam by the change in internal energy with constant entropy, it is sometimes desirable to calculate the work done from the change in pressure of the steam as its volume increases. A mathematical relation must then be available between the pressure P and the volume V of the steam during adiabatic expansion. It is customary to use a relation of the form

$$P V^k = P_1 V_1^{\,k} = P_2 V_2^{\,k}$$

where the adiabatic exponent k is taken as constant. Applying logarithms, we have

$$\log P_1 + k \log V_1 = \log P_2 + k \log V_2$$

$$\text{Whence,} \quad k = \frac{\log P_1 - \log P_2}{\log V_2 - \log V_1}$$

Substituting values of pressure and volume from the above example, we find the adiabatic exponent

$$k = \frac{\log 200 - \log 14.696}{\log 22.89 - \log 2.285} = 1.133$$

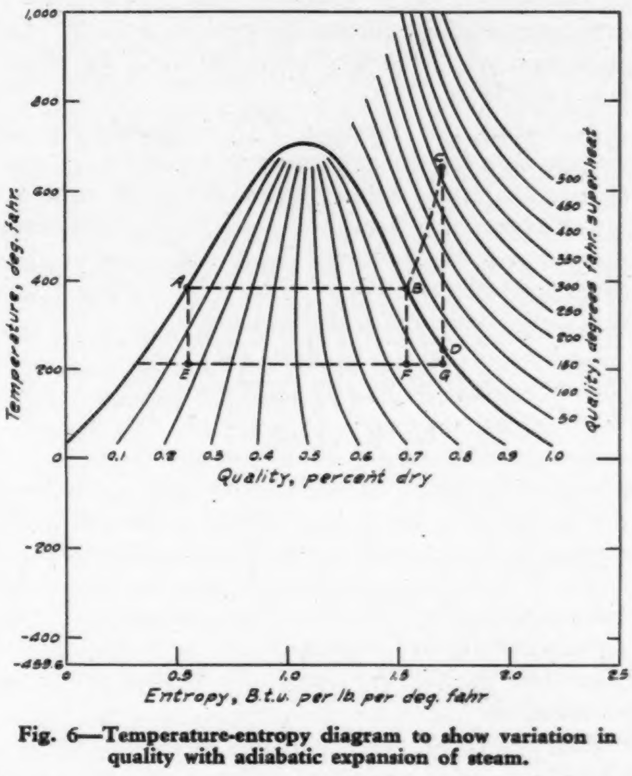


Fig. 6—Temperature-entropy diagram to show variation in quality with adiabatic expansion of steam.

The value 10/9 was proposed by Rankine for the exponent of adiabatic expansion of wet steam. The work done during expansion according to the above relation is

$$W = \int_{V_1}^{V_2} P\, dV = \frac{P_1 V_1 - P_2 V_2}{k - 1}$$

Substituting the values of the initial and final pressure and volume, we have

$$W = \frac{144}{1.133 - 1}(200 \times 2.285 - 14.696 \times 22.89)$$
$$= 130{,}585 \text{ ft. lb. per lb. of steam}$$

Expansion with P V Constant

The expansion line of steam in an engine cylinder after cut-off, obtained by means of the steam engine indicator, invented by Watt, apparently showed the product of the pressure and volume to be constant while the steam expands. During the development of the steam engine in the first half of the 19th century, this relation was also taken as representing the variation of the volume of dry saturated steam with

its pressure. In accordance with Watt's law that the sum of the sensible heat and the latent heat of steam was constant and in accordance with the caloric theory that no heat disappeared when mechanical work was done, steam initially dry and saturated was assumed to remain in this condition during expansion. The fact that steam partly condenses during expansion in an engine cylinder as explained in a previous section, was first deduced in 1850 by both Clausius and Rankine from Joule's experiments on the equivalence of heat and work and Regnault's experiments on the thermal properties of steam. This deduction was confirmed experimentally by Hirn a few years later.

Although the relation P V = constant is not strictly true for the expansion of steam, it is a sufficiently accurate assumption to make when constructing an expected indicator diagram for predetermining the power to be developed by an engine under given conditions of cut-off, etc. The work during expansion only according to the relation

$$P\,V = P_1\,V_1 = P_2\,V_2$$

may be calculated by the expression

$$W = P_1\,V_1 \log_e \frac{V_2}{V_1}$$

where subscript 1 refers to the initial condition and subscript 2 refers to the final condition. This expression is derived by integrating the elemental work $dW = P\,dV$ between the limits V_1 and V_2 after substituting $P = P_1V_1/V$. The thermal changes accompanying such expansion of steam may be calculated by the aid of tables of the thermal properties of steam.

Thus, consider the expansion of steam which is initially dry and saturated under a pressure of 200 lb. per sq. in. absolute, to atmospheric pressure in accordance with

$$P\,V = P_1\,V_1 = P_2\,V_2$$

Since $V_1 = 2.285$ cu. ft. per lb., we have
$V_2 = 200 \times 2.285 / 14.696 = 31.10$ cu. ft. per lb.
The work done by the steam during expansion is

$$W = P_1\,V_1 \log_e \frac{V_2}{V_1} = 144 \times 200 \times 2.285 \log_e \frac{31.10}{2.285}$$
$$= 171{,}820 \text{ ft. lb. per lb. of steam}$$
$$= 220.7 \text{ B.t.u. per lb. of steam}$$

Since the specific volume of dry saturated steam under atmospheric pressure is 26.82 cu. ft. per lb., the final volume of 31.10 cu. ft. per lb. shows that the steam is superheated after expansion. Interpolating in the superheated steam tables, we find the total heat to be 1198.8 B.t.u. per lb. and the temperature to be 314 fahr. after expansion. Also,

$$Apv = \frac{144 \times 14.696 \times 31.10}{778.6} = 84.5 \text{ B.t.u. per lb.}$$

Hence, internal energy in steam after expansion is 1198.8—84.5 = 1114.3 B.t.u. per lb. Since the initial internal energy, as calculated in a preceding paragraph, is 1113.3 B.t.u. per lb., there has been a slight increase in internal energy during expansion equal to 1114.3—1113.3 = 1.0 B.t.u. per lb. In order to perform the external work equivalent to 220.7 B.t.u. per lb. while the internal energy of the steam increases 1.0 B.t.u. per lb., heat must be added to the steam during expansion equal to 220.7 + 1.0 = 221.7 B.t.u. per lb.

Polytropic Expansion

Very careful measurements of the expansion of steam in engine cylinders show that the relation between the pressure and volume can be more closely represented by an expression of the form

$$PV^n = P_1\,V_1^{\,n} = P_2\,V_2^{\,n}$$

than by the simpler expression with n = 1. For n equal to any other value than unity, the work done during expansion only is

$$W = \frac{P_1\,V_1 - P_2\,V_2}{n-1}$$

where the subscripts 1 and 2 refer to the initial and final conditions respectively. This expression is derived by integrating the elemental work $dW = P\,dV$ between the limits V_1 and V_2 after utilizing the relation $P\,V^n = P_1\,V_1^{\,n} = P_2\,V_2^{\,n}$ to eliminate P.

No numerical example will be given of polytropic expansion; the calculations would be similar to those presented for the preceding case.

Isothermal Expansion

When heat is added to a fluid during expansion in just sufficient quantity to keep the temperature constant, the expansion is said to be isothermal. The generation of steam from water in general occurs at constant temperature so that isothermal expansion of wet steam is of great practical importance. Isothermal expansion of superheated steam, however, is of no practical importance and of little theoretical interest.

Thermal Changes at Constant Volume

An example of thermal change at constant volume is the heating of steam and water in a boiler or other vessel while the outlets are closed. Since no external work is done, the heat added must equal the increase in internal energy of the water and steam.

Consider a mixture in a vessel consisting of 10 per cent steam and 90 per cent water by weight under a pressure of 200 lb. per sq. in. absolute. Let us find the quantity of heat per lb. of mixture which will raise the pressure to 400 lb. per sq. in. absolute. The initial volume of the mixture is $0.01839 \times 0.9 + 2.285 \times 0.1 = 0.0166 + 0.2285 = 0.2451$ cu. ft. per lb., the specific volumes of water and steam being taken from Keenan's Steam Tables. Let x be the steam fraction under 400 lb. per sq. in. absolute pressure, then $0.0194\,(1-x) + 1.1601x = 0.2451$, or $x = 0.1979$ lb. of

(Continued on Page 46)

Submerged Combustion

By
DAVID BROWNLIE
LONDON

A Remarkable Development in the Field of Fuel Technology

Mr. Brownlie describes a submerged combustion burner which evidently is finding successful commercial application in Great Britain. This idea seems to have many possibilities and it will be interesting to watch its further development. Apparently the appplications thus far have, for the most part, been limited to the use of gas as fuel. The author's remarks as to the possibilities of this development in connection with house and building heating may have particular significance for us in view of the widespread and rapidly increasing availability of natural gas in this country.

SINCE 1886, when Collier took out a British patent on the subject, inventors have struggled with the fascinating problem of burning a flame continuously under the surface of water or other liquids such as solutions of gases, liquids, and solids in water and solvents generally, organic compounds such as mineral, animal and vegetable oils, fats, and waxes, and molten metals.

The advantages of such submerged combustion include simplicity, cheapness of equipment, and a very high rate of heat transmission to the liquid. It may be remembered that Oscar Brunler labored for many years to apply this method to steam generation and developed the "Brunler" boiler having the flame in the boiler itself below the water level. This gave a high thermal efficiency but all the gaseous products of combustion mixed with the steam, a condition which could not be corrected and which still appears to be an insurmountable difficulty.

The field of application for a successful method of submerged combustion is a very wide one quite apart from steam and power, including particularly the evaporation of all kinds of liquids, promoting chemical reactions of various kinds, the melting of metals, and the heating of water, especially in connection with the central heating of buildings. In order that a flame shall keep alight under water the rate of heat generation, which is dependent upon the amount of fuel and air burned in a given unit of time, must be enormously increased as compared with ordinary methods in order that the loss of heat to the surrounding water is not sufficient to cause the temperature to fall below the combustion point.

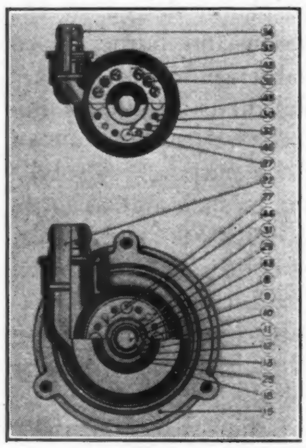
The general theories of submerged combustion have long been understood by a number of people but the method has proved to be an extremely difficult one to carry out in practice. However, success under commercial conditions is now being attained in Great Britain by Submerged Combustion, Ltd., of London with which organization C. Featherstone Hammond, who recently read a paper on the subject before the Institute of Fuel in London, is associated, and it is the object of the present article to give a brief description of the Hammond system, following upon a personal investigation of the matter.

Essentially the basic principle of design in the "Hammond" submerged combustion burner is to provide for the extraordinarily rapid and intimate mixing of the air with the fuel, so as to obtain complete combustion with the theoretical amount of air, accurately measured for the purpose. Also the rate of combustion is increased to such an enormous extent that it is claimed to be, with gas for example, several hundred times that of solid fuel with forced draft and to amount to the evolution of about 20,000,000 B.t.u. per hour per cubic foot of combustion space. Further, the design is such that it is impossible for the flame to flash back into the burner; hitherto this has been one of the great difficulties of submerged combustion.

Thus far, for the most part, gas has been used as fuel, and the basic arrangement, subject to numerous minor modifications, consists in the use of a small electric driven duplex booster which supplies separately the gas and air for combustion under pressure, generally at about 5.0 lb. per sq. in., to a proportioning valve. In normal operation, the adjustment is such as to give exactly the theoretical amount of air for combustion. In London, for example, with domestic gas of 500 B.t.u. per cubic foot the figures are 4.70 volumes of air and 1.00 volume of gas. These correct volumes of gas and air are then passed to the burner in the top of which is a mixing chamber of special design which is one of the most important features. The mixture of air and gas then passes down through a connecting passage to the combustion chamber or burner proper, lined with a refractory material, Alundum, where the gas burns, the combustion gases, nitrogen and CO_2 passing out at the bottom into the liquid, the greater part of the burner being below the surface.

On these lines, the "Hammond" burner is being

used in commercial applications for evaporating many different liquids, central heating of buildings, melting metals, the polymerising of oils, and operating closed dye vats, while many new applications are under active consideration.



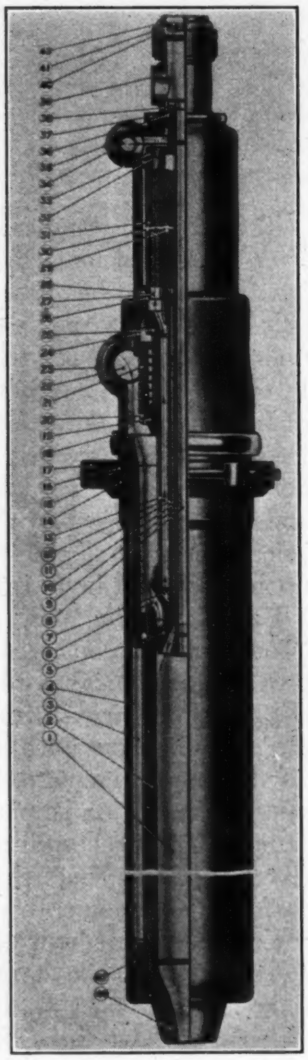


Fig. 1—Detailed view of the Hammond Submerged Combustion Burner

Item No.	Description	Item No.	Description	Item No.	Description
1	Chamber, Combustion	17	Register, Clamp	32	Passage, Gas
2	Lining, Refractory	18	Body, Main	33	Carrier, Upper
3	Annulus, Insulating	19	Ring, Split	34	Inlet, Gas
4	Casing, Outer	20	Collar, Spring	35	Connection, Gas
5	Transfer, Terminal	21	Spring	36	Ring, Piston
6	Port, Air Transfer	22	Inlet, Air	37	Cover, Main Body
7	Port, Inlet	23	Connection, Air	38	Ring, Securing
8	Passage, Flame Sight	24	Seating, Spring	39	Connection, Ignition
9	Tube, Flame Sight	25	Sleeve, Air Transfer	40	Glass, Aperture
10	Passage, High Velocity			41	Washer
11	Tube, High Velocity	26	Carrier, Lower	42	Nut, Flame Sight
12	Passage, Air Transfer	27	Passage, Air	43	Screw, Pack Securing
13	Tube, Air Transfer	28	Ring, Piston	44	Jet, Gas
14	Ferrule	29	Passage, Mixture	45	Jet, Air
15	Flange	30	Jet Plate, Gas	46	Nozzle
16	Casing, Air Transfer	31	Jet Plate, Air	47	Endcap

Fig. 1 shows a detailed view of the Hammond burner. At the top, in the burner head, is the mixing chamber to which connect the pressure air and gas supply pipes from the proportioning valve. A transfer passage or duct connects this chamber to a tubular combustion chamber, comprising the main portion of the burner and terminating in a nozzle. The passage connecting these chambers is so designed that the minimum velocity of the intimately mixed downcoming gas and air is always more than the backward rate of flame propagation, about 3.3 feet per second. For this reason back-travel of the flame is impossible. In the standard design illustrated, the transfer passage is kept cool by the incoming cold air so that the metal cannot heat up sufficiently to cause ignition in the mixing chamber.

The combustion chamber is lined with Alundum which, it is said, will operate continuously for an almost unlimited period within a temperature range of 1292 to 2732 deg. fahr. In one case, for example, the original lining of a burner has been in use for over 3000 burning hours. The material used for the outer casing depends upon the type of service required. Among the materials which have been found suitable for various applications are cast iron, steel, copper, gunmetal, phosphor bronze, enamelled cast iron, chromium plated gunmetal, and acid resisting stoneware or glass. Hammond burners are made in seven standard sizes in capacities ranging from 30,000 B.t.u. to 1,000,000 B.t.u. per hour.

The mixing chamber in the head of the burner is of very ingenious design. It is built up of a series of small thin steel laminae fixed on top of one another, and forming a "pack" circular in plan view, with a large hole in the center, and perforated according to a special plan. The perforations provide a series of vertical channels or tubes which all communicate to the central hole or mixing chamber by axial ducts. These vertical tubes are of two sizes, one set of smaller size being for the gas and the other and larger size for the air, with pipe connections accordingly. Also these gas and air supply tubes have a whole series of minute axial ports leading to the central mixing tube, alternate laminae being stamped one with air channels and the other with gas channels to form a large number of these ports. This design provides, almost instantaneously, a violent and intimate mixing, on turbulent principles, of the gas and air, both at 5.0 lb. pressure, as previously stated, so that complete combustion takes place with the theoretical proportions.

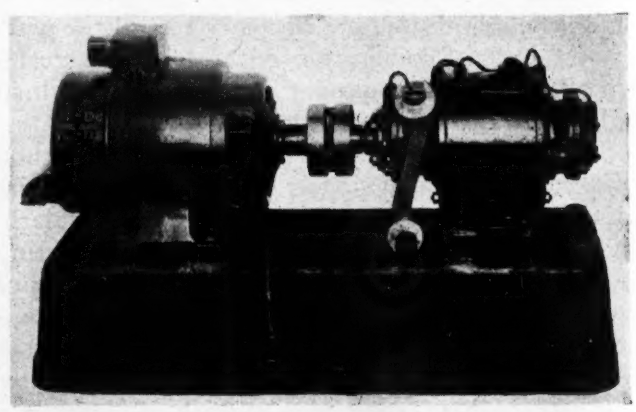


Fig. 2—Standard air and gas booster for unit of 125,000 B.t.u. per hour.

The duplex electric-driven gas and air booster sets are located on the same base plate with a common driving shaft and one motor, and are designed in standard sizes ranging from a 0.5 hp. unit, ca-

pable of handling 120 cu. ft. of gas and 540 cu. ft. of air per hr. (60,000 B.t.u. per hr. with 500 B.t.u. gas) to a 7.5 hp. unit, handling 2000 cu. ft. of gas, and 9000 cu. ft. of air per hr. (1,000,000 B.t.u. per hr.)

The proportioning valve, used to adjust with great accuracy the volumes of the gas and air, as delivered by the booster, is of the piston type without glands, and provided with piston rings to make the whole arrangement gas tight, the separate volumes, being controlled by ports in the piston registering with inlet and outlet ports in the body of the valve so designed that the rotation of the piston varies the cut-off on the gas port without altering the cross sectional area of the air port. Naturally the respective volumes depend upon the heating value of the gas and are always regulated according to the theoretical amounts for perfect combustion, while it is a very simple matter also to give a reducing or an oxidizing flame to any desired degree.

One remarkable feature of submerged combustion, which accounts for the high heat transmission efficiency, is the fact that the combustion gases are discharged through the liquid in the form of a vast number of extremely small bubbles, almost invisible to the naked eye. This can be observed by means of a large glass bowl filled with water having a burner fixed at the top and the flame well down below the water level. No large bubbles are to be seen, as might be expected, but there is an extreme subdivision of minute bubbles with a general appearance resembling aerated water. It is believed these combustion gas bubbles only average the equivalent of about one-thousandth of an inch cube so that within a volume of 1 cu. ft. the actual effective contact of the white hot combustion gases and the water is equal to about 1.65 acres in extent of ordinary contact between a volume of gas and the surface of water at rest. For this reason, one of the most important possibilities of submerged combustion is the air lift pump, using the products of combustion from the burner in the water or other liquid instead of expensive compressed air.

A most interesting application of the Hammond submerged combustion system, is the central heating of buildings, using domestic gas. Apart from the simplicity of this system and the elimination of the dirt, smell, dust, and ash associated with ordinary solid or liquid fuel firing, one advantage is that the equipment can be placed at any point in the building or on the roof if desired. It is not necessary to use the cellars for this purpose as with ordinary gravity circulation, and no chimney need be provided.

Fig. 3 shows the general arrangement of a central heating unit on these lines, with the submerged combustion burner at (1), a circulating chamber or air lift foot piece at (2), an expansion tank in which the water level is shown (3), and a rising main (4) surmounted by a head tank (5). This latter is maintained full of hot water by the action of the burner which heats and aerates the column of water in the rising main (4) and from this tank the hot water flows by gravity through the outlet (6), the head resulting from the hot water displacing the

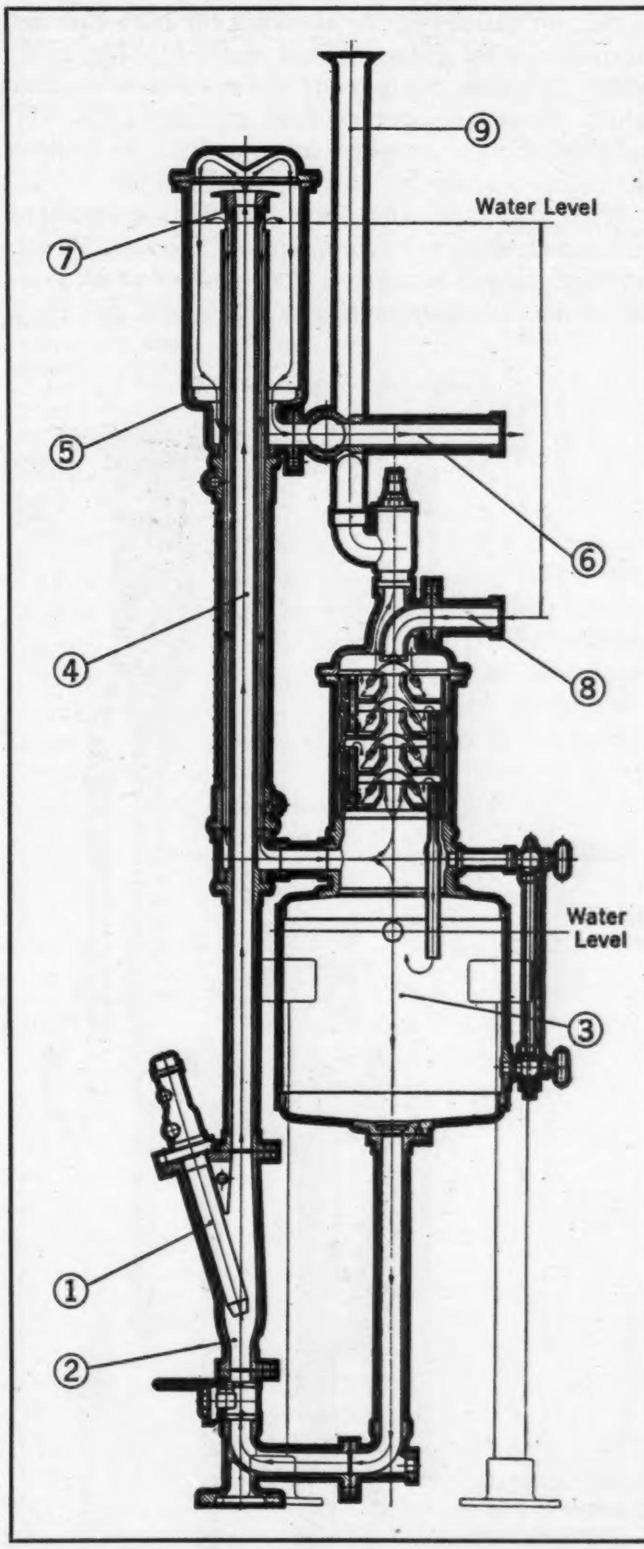


Fig. 3—Hammond Submerged Combustion unit for the central heating of buildings using domestic gas

cold water throughout the circuit. Also the head tank (5) has a deflector cover upon which the aerated column of hot water impinges, thus separating the steam and gases from the water. Then the steam

and gases descend by an annular passage (7), surrounding the rising main, and leave the system by way of a heat exchange device in counterflow with the return cold water from the radiator circuit which enters at (8) with final discharge of the gases at the top outlet (9). As showing the high thermal efficiency, these gases are only about 120 deg. fahr. when the room temperature maintained is 64 deg. fahr., about 94.5 per cent of the gross calorific value of the gas supplied being utilized as well as the latent heat of the water of combustion.

With regard to the space required, a standard Hammond duplex heating set of 2,000,000 B.t.u. per hour output occupies a floor area of 38.0 sq. ft. above the operating level and 23.0 square feet for a depth of 7 ft. 6 in. below, about one-tenth of the space required for a coal or coke installation of the same output. For central heating, single units are standardized in sizes from 60,000 B.t.u. per hr. with a 1/2 hp. electric drive to 1,000,000 B.t.u. with a 7 1/2 hp. drive. The whole operation is entirely automatic and if necessary can be started and stopped by distant push button control, and, further, the degree of the heating may be controlled with the aid of a thermostatic regulator by the heat of the building.

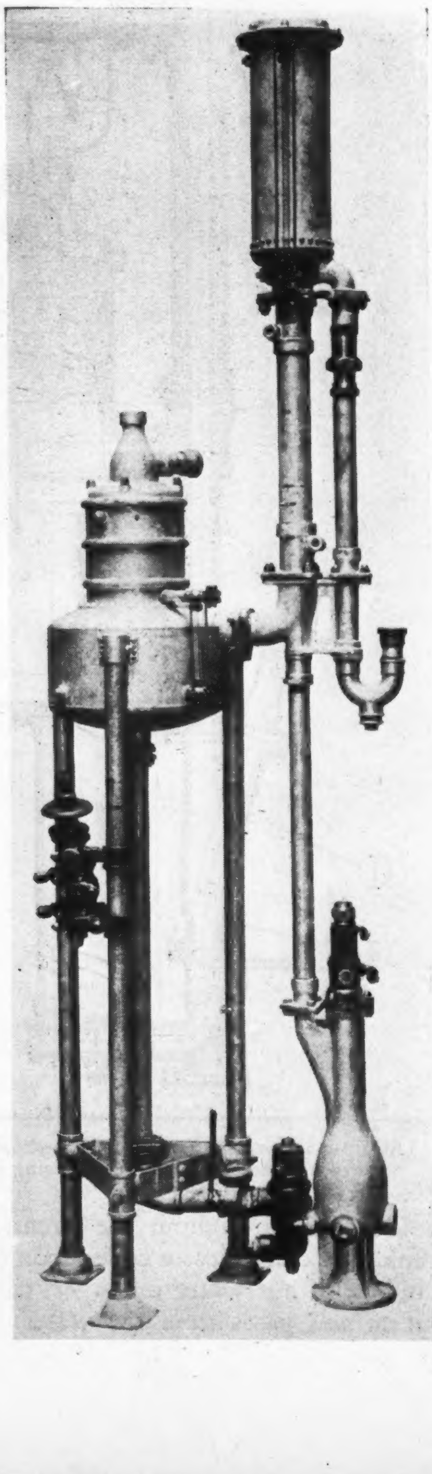


Fig. 4—Photograph of Hammond unit for house and building heating using domestic gas

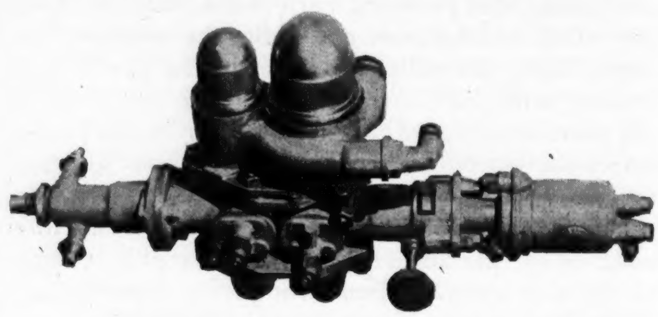


Fig. 5—Proportioning valve used with Hammond System (250,000 B.t.u. per hour size) for supplying air and gas under pressure to the burner with very accurate control

Another important application of submerged combustion is in connection with the evaporation of extremely difficult liquids, such as phosphoric acid and sulphuric acid, using earthenware, glass, or porcelain vessels, with the burner fixed in the top. For example, an installation was recently supplied for the continuous evaporation of phosphoric acid consisting of a battery of 3 earthenware units, each of 7.1 gal. capacity occupying 22.6 sq. ft. total floor space. This plant runs for 120 hr. a week and pro-

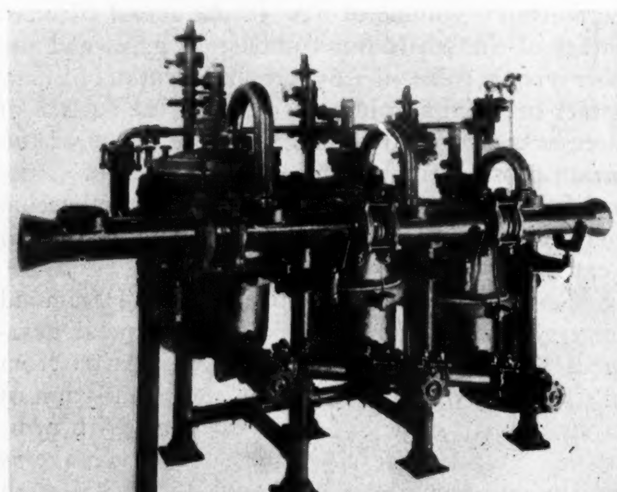


Fig. 6—Hammond Submerged Combustion three unit battery for the concentration of phosphoric acid using earthenware containers to eliminate corrosion difficulties.

(*Continued to page 46*)

Greatly Improved Efficiency Follows Modernizing of Central Power Plant Serving R. I. Institutions

(*Continued from page* 23)

The coal cost of producing a 1000 lb. of steam from and at 212 deg. fahr. shown at \$0.272 is based on data compiled on the h.r.t. units on December 21 and 22, 1928. This figure must be considered very low and only attained under test conditions. The writer firmly believes that prior to this test the cost was very much higher.

The coal cost of producing a 1000 lb. of steam from and at 212 deg. fahr. shown at \$0.2205 is based on data compiled on the water tube unit on June 5 and 6, 1929. This would represent the average cost of producing 1000 lb. of steam from and at 212 deg. fahr. on \$5.82 coal.

The actual coal cost of producing 1000 lb. of steam from and at 212 deg. fahr. shown as \$0.252 is based on the yearly cost, using coal averaging \$6.18 per gross ton as against \$5.82 as shown on test data.

The amount of convict labor involved in the boiler plant reduces our operating cost to a great extent. These figures could not be used for comparative purposes, therefore, the writer bases all his figures on the cost of coal for generating 1000 lb. of steam from and at 212 deg. fahr.

No data is given covering flue gas analysis due to the fact that only forty-eight tests were made. Although the CO_2 content averaged better than 13 per cent on the water tube unit, the writer does not feel that there were sufficient tests made to call this an absolute average figure.

AVERAGE YEARLY OPERATING DATA AND ECONOMY

Total coal consumed Dec. 1, 1928 to Dec. 1, 1929	27,498,755 lb.
Total coal consumed corrected for moisture content	26,451,053 lb.
Average heat content of coal as received	14,121.6 B.t.u.
Average heat content of coal, dry basis	14,736.1 B.t.u.
Average moisture content in coal as received	3.81 per cent
Total water pumped to boilers Dec. 1, 1928 to Dec. 1, 1929	271,927,800 lb.
Total water blown from boilers Dec. 1, 1928 to Dec. 1, 1929	1,430,000 lb.
Total steam generated F. and A. 212 deg. fahr. Dec. 1, 1928 to Dec. 1, 1929	300,901,753 lb.
Factor of evaporation	1.1124
Average steam pressure	100.3 lb. gage
Average feed water temperature	210.69 deg. fahr.
Average temp. of hot water delivered to institutions	172.00 " "
Average steam temp.	468.10 " "
Average flue gas temperature	460.00 " "
Average temp. of condensate returning to power plant	152.78 " "
Average low pressure in heating main	4.33 lb. gage
Evaporation per lb. of coal as received F. and A. 212 deg. fahr.	10.94 lb.
Evaporation per lb. of Dry Coal F. and A. 212 deg. fahr.	11.37 lb.
Average thermal overall efficiency of the boilers	74.87 per cent
Actual cost of coal (6.18—2240 lb.) as fired required to evaporate 1,000 lb. of steam F. and A. 212 deg. fahr.	\$0.252

Although the power plant was not taken into consideration in describing the station the following figures, representing totals for the period January 1 to December 1, 1929, give an idea of the importance of its service: kilowatt-hours generated—515,129; gallons of water pumped to institutions—207,953,380; pounds of ice manufactured—946,825; total dry refrigeration load (tons)—3,480.

STATE of RHODE ISLAND and PROVIDENCE PLANTATIONS

CENTRAL POWER STATION HOWARD, R. I.

WEEKLY RECORD WEEK ENDING

MONTH	DAY	YEAR
6	15	1929

Electric Plant - - Refrigeration Plant - - Boiler Plant

	SUNDAY	MONDAY	TUESDAY	WED'SDAY	THURSDAY	FRIDAY	SATURDAY	TOTALS
Engines In Service	2	2	2	2	2	2	2	
Engine Hours Run	24	24	24	24	24	24	24	168
Compressor Hours Run	24	24	24	24	24	24	24	168
Boilers Now In Service	1	1	1	1	1	1	1	
Boiler Hours Run	24	24	24	24	24	24	24	168
Blowers In Service	1	1	1	1	1	1	1	
Blower Hours Run	24	24	24	24	24	24	24	168
Feed Pumps In Service	1	1	1	1	1	1	1	
Feed Pump Hours Run	24	24	24	24	24	24	24	168
Domestic Water Pump Hours Run	22	22	22	22	22	22	22	154
Fire Pump Hours Run	--	--	--	--	--	1	--	1
Average Steam Pressure	100	100	99	99	99	99	99	99
Average Low Pressure	4	4	4	5	5	4	5	4.4
Average Feed Water Temp	210	213	213	217	215	215	215	214
Average Return Water Temp	134	138	138	141	136	135	140	137
Average Flue Gas Temp	469	465	460	468	492	480	481	
T. Equiv Evap. F. & A. 212°	496056	287071	413861	384830	356968	413923	333035	2,688,764
Equiv Evap F & A 212° Dry Fuel Per Lb	11.95	11.68	12.09	12.56	12.29	12.36	11.85	12.12
Total Lbs Coal Received	--	--	--	--	--	--	--	
Total Lbs Coal Consumed	42330	28080	34960	33640	29640	34200	30400	228278
Balance On Hand Gross Tons	2150.00	2140.81	2131.21	2117.99	2104.73	2089.49	2075.92	

GENERAL REPAIRS

ITEMS	LABOR AMOUNT \$	MATERIAL AMOUNT \$	TOTAL AMOUNT \$
Relocating Brine Tank Motor on new form	\$ 9.82	--	\$ 9.82
Repairs on 10" Steam Main in Tunnel			32.49
			\$ 42.31

SUPPLIES

ITEMS	AMOUNT	AMOUNT \$
White Cotton Waste @ 10¢ per lb.	100#	10.00
Druluco Green Cup Grease #2	25#	3.25
2 Drums Calcium Chloride \$1.87 per 100#	750#	13.09
Harris Ammonia Compressor Oil	10 gals.	7.00
2 Drums Calcium Chloride	750	13.09
Jaws and Nuts for 24" Stillson Wrench	2	2.30
" " " " 18" " "	2	1.34
" " " " 10" " "	4	1.40
Single Wheel Pipe Cutter 1" - 2"	1	4.50
Cutters for above #25	3	.90
Machine Bolts 5/8" x 2"	12	.27
Hack Saw Blades	12	.43
Coal Received 0		
Coal Consumed 228278 @ \$5.82	101.91	597.08
		\$ 654.97

REMARKS

LABOR

NAME OF EMPLOYEE	CLASS	TOTAL PAY
Mr. ----	Engineer	\$ 47.30
Mr. ----	"	40.00
Mr. ----	"	41.96
Mr. ----	"	38.46
Mr. ----	Water Tender	34.96
Mr. ----	" "	33.00
Mr. ----	" "	34.96
Mr. ----	Fireman	30.80
Mr. ----	"	30.00
Mr. ----	"	31.96
Mr. ----	"	31.96
Mr. ----	Utility	34.96
Mr. ----	Steamfitter	
		430.72

LABOR

NAME OF EMPLOYEE	CLASS	TOTAL PAY
Convict Labor	(Laborers)	48.50
		430.72
TOTAL PAYROLL		\$ 479.22

RECAPITULATION

TOTAL COST OF REPAIRS	42.31
TOTAL COST OF SUPPLIES	654.97
TOTAL COST OF PAYROLL	479.22
GRAND TOTAL	\$ 1176.50

Signed *Chas. E. Blair*

Weekly record sheet of Howard central plant.

How to Compare the Relative Value of Different Fuels

By B. J. CROSS, Combustion Engineering Corporation, New York

THE true measure of the value of a fuel for use under steam boilers is the cost of a unit of steam produced by it. Units of fuel such as tons of coal, gallons of oil or cubic feet of gas are not definite units of heat. Such units must be modified by the heat units they contain and by the efficiency with which these heat units can be converted into heat in the form of steam.

The accompanying chart has been prepared to permit a comparison of fuels on the basis of the cost of one million B.t.u. in the form of steam, or roughly, the cost of one thousand pounds of steam. Only simple arithmetical relations are involved. The scale at the bottom of the chart gives the unit prices for coal, oil and gas. From the cost of the fuel and its heat value in B.t.u., the cost of one million B.t.u. in the fuel may be determined and is shown in the right hand vertical scale. The cost of one million B.t.u. in fuel and the efficiency of burning and absorption give the fuel cost of one million B.t.u in the form of steam. The fuel cost of one thousand pounds of steam may be obtained by multiplying the cost per million B.t.u. in steam by $\frac{H}{1000}$. As H, the heat added to one pound of water will vary in different installations, the fuel cost of one thousand pounds of steam must be determined individually for each installation. The fuel cost of one million B.t.u. will, however, be a direct measure of the relative value of different fuels.

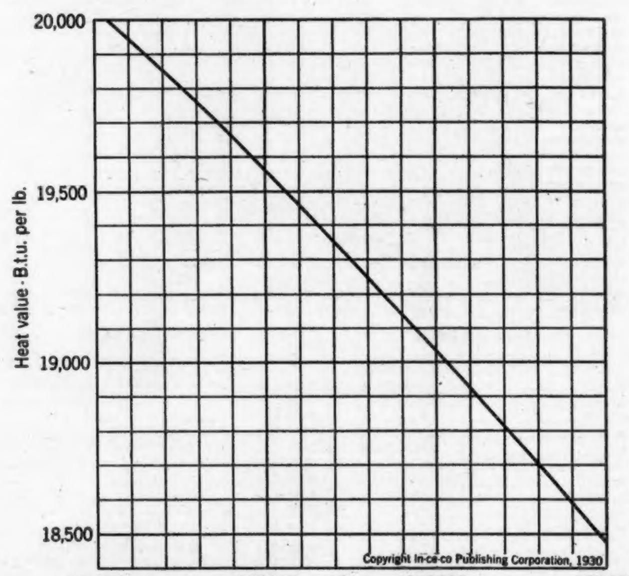
If a coal of 14,000 B.t.u. per pound costs $4.50 per ton, the cost of one million B.t.u. in the fuel will be 16.07 cents. If this coal is burned and the heat absorbed at 75 per cent efficiency, the fuel cost of the steam produced would be 21.4 cents. To obtain the equivalent price of oil with a heat value of 18,500 B.t.u. per pound, trace downward from this cost of steam, 21.4 cents per million B.t.u., to the efficiency of conversion with oil, for example 80 per cent; from this intersection trace horizontally to the line for the heat value of the oil, 18,500 and from this intersection trace downward to the price of oil, cents per gallon.

For equal fuel cost of steam, an operator who can obtain 14,000 B.t.u. coal at $4.50 per ton cannot pay more than 2.55 cents per gallon for 18,500 B.t.u. oil, or 2.3 cents per gallon for 20,000 B.t.u. oil at efficiencies of conversion of 75 per cent and 80 per cent for coal and oil respectively. In the same manner it may be seen that the equivalent cost of natural gas of 1000 B.t.u. per cubic foot and 75 per cent efficiency will be 16 cents per 1000 cubic feet.

In making a comparison of fuels by means of this chart, it should be born in mind that the cost of one million B.t.u. in steam as given is the fuel cost only. The labor, maintenance and investment costs will also vary with the type of fuel used.

It will be noted that the B. t.u. lines for oil are in inverse order to those for coal; that is, the cost of one million B.t.u. in fuel is higher for the oils of higher heat value than for those of lower heat value, expressed in B.t.u. per pound. This is because of the lighter density of the high B.t.u. oils. An oil with a heat value of 20,000 B.t.u. per pound will weigh about 6.8 pounds per gallon while an oil of 18,500 B.t.u. per pound will weigh about 8 pounds to the gallon.

The price of oil is quoted on a volume basis, that is, in cents per gallon while the heat value is determined on a weight basis, B.t.u. per pound. The heat content of oil in B.t.u. per gallon is of more interest to the purchaser than the B.t.u. per pound. The approximate relation of the heat value per pound and the heat value per gallon is given in the chart below. The B.t.u. per gallon may of course be computed exactly when the B.t.u. per lb. and the specific gravity are known.



Relation between heat value per pound and heat value per gallon for fuel oil.

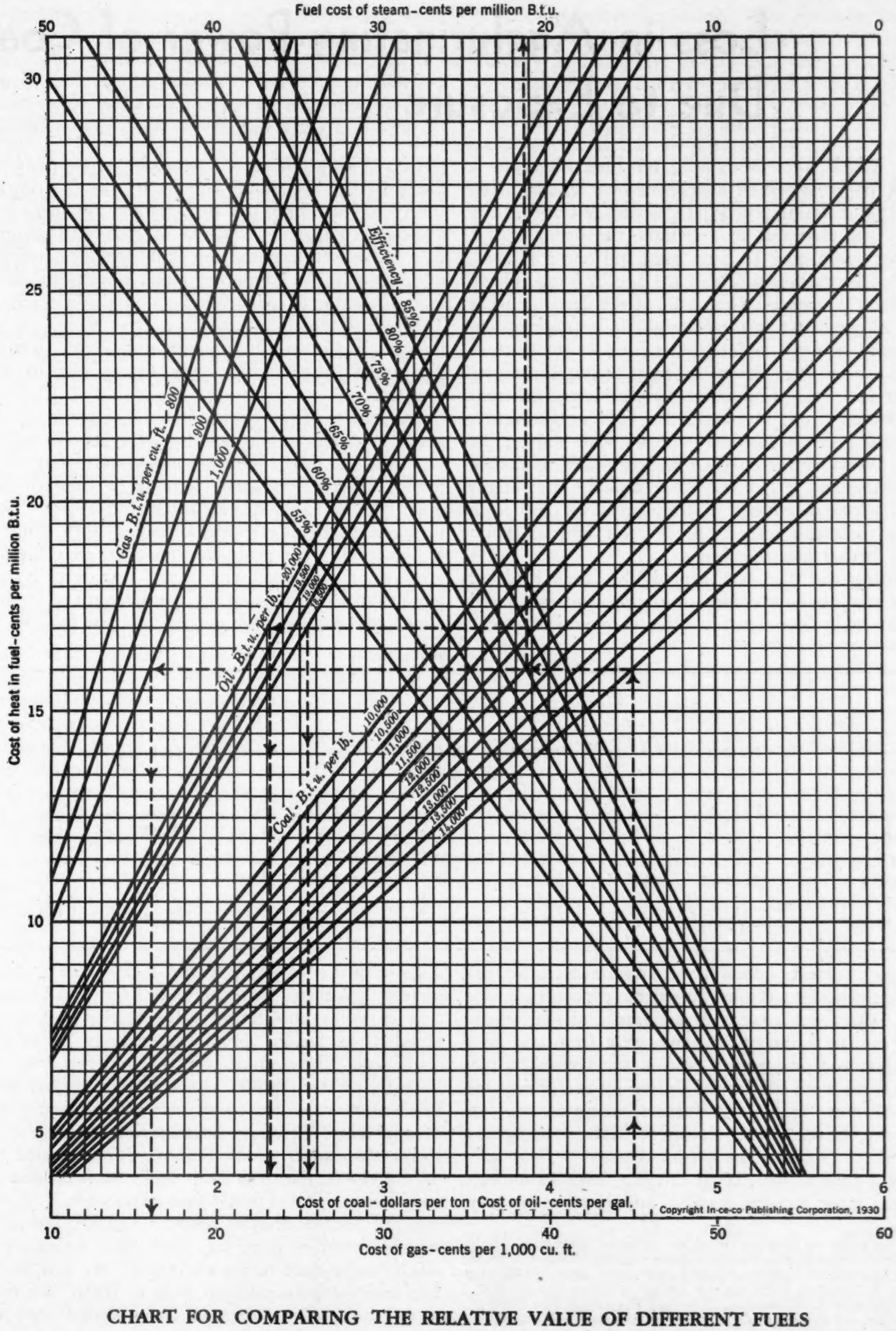


CHART FOR COMPARING THE RELATIVE VALUE OF DIFFERENT FUELS

No. 11 of a series of charts for the graphical solution of steam plant problems

Loss in Agglutinating Power of Coal Due to Exposure*

A YEAR ago, Marshall and Bird presented a paper in which a new method of measuring the agglutinating power of coal was described. The procedure used was to determine the strength of a button containing 10 parts sand and one part coal, formed by carbonizing the mixture in a crucible in an electric furnace. The result of the determination was reported as the total weight in grams required to bring about complete destruction of the button. Correlations were shown between the agglutinating value and some of the characteristics of the different coals that were investigated. This agglutinating test has been in use fairly continuously during the past five years for coals of widely differing coking qualities, and it has shown reasonably concordant results accurate enough for commercial use, although there are many features of the test which should have further scientific study.

During the past year a study has been made of some coals of low coking strengths, and incidental to the main investigation some data which appear to be of interest and value were obtained on the loss in agglutinating power caused by exposure to the air. Three coals were investigated, all of which were of the Tertiary age; two were from one field in Asia, and one from a field in the United States. The three were similar, as shown by the proximate and ultimate analyses in Table 1, except for the ash content. In the second section of Table 1 the figures have been put upon an ash-free basis.

As a general rule, coals initially high in oxygen absorb more oxygen readily, and if they initially possess coking qualities, the coking strength is reduced by the exposure. These tests gave an opportunity to learn how the analyses and agglutinating qualities compared. Samples of each coal ground to 40 mesh were exposed in a thin layer for a number of months in the laboratory under conditions much more favorable to oxidation than obtain in practice. The results which follow show that there was an increase in the oxygen contents and a very definite decrease in the agglutinating values due to the exposure.

The results of the coking index measurements are given in Table 2. The samples were kept in sealed jars from the time they were mined until they were tested; nevertheless some decrease in strength unquestionably occurred prior to the initial test. This is indicated by the results obtained with samples RG and SG. It is probable, however, that the agglutinating value shown by the first tests is not more than 10 per cent below the strength of freshly mined coal for coals SA and RA and less for coal P.

TABLE 1.—*Coal Analyses*

Coal	Proximate Analysis: Ash, Per Cent	Volatile Matter, Per Cent	Fixed Carbon, Per Cent	Ultimate Analysis: C, Per Cent	H, Per Cent	N, Per Cent	S, Per Cent	O, Per Cent
				MOISTURE-FREE				
SA..........	16.11	39.95	43.94	67.50	5.15	1.62	0.84	8.78
RA..........	15.80	38.39	45.81	68.50	4.99	2.34	0.94	7.34
P...........	6.02	40.41	53.57	75.88	5.39	1.69	1.07	9.95
				MOISTURE-FREE AND ASH-FREE				
SA..........		47.63	52.37	80.47	6.14	1.93	1.00	10.46
RA..........		45.60	54.40	81.35	5.93	2.89	1.11	8.72
P...........		43.02	56.98	80.73	5.74	1.80	1.14	10.59

Tests on Coals SA, RA and P in Table 2 show clearly that there is a definite and continued reduction in the agglutinating value as the coal is exposed to oxidation. From the analyses, all of the coals seem to be alike, yet RA and SA drop off with far greater rapidity in their coking values than P. This may be due to an increased susceptibility to oxidation, or other deterioration, because of a slight absorption which occurred in the sealed jar during the period of several weeks between mining and testing. This is partly demonstrated by a second series of tests made upon coals SA and RA, but upon separate samples from jars that were sealed for a much longer time before the initial test was made. The interval between zero days in these two tests is 139 days. The results of these second tests are also shown in Table 2.

From these tests it is apparent that during the

* This paper was presented before the American Institute of Mining and Metallurgical Engineers at their annual meeting, February 17 to 20, 1930. It represents work done under a co-operative agreement between the U. S. Bureau of Mines and the College of Mines, Seattle, Wash. The authors are S. M. Marshall, Consulting Engineer in New York; H. F. Yancey, Acting Supervising Engineer, U. S. Bureau of Mines, Northwest Experiment Station, Seattle, Wash., and A. C. Richardson, Assistant Mining Engineer, U. S. Bureau of Mines, Southern Experiment Station, Tuscaloosa, Ala.

long interval of 139 days there was a reduction of approximately 1000 g. in the agglutinating value of both of these coals, but that after the jars had been opened and the coals exposed to the atmosphere there was a further drop of over 1500 g. in 7 days, a much more rapid diminution in strength than was shown by the original samples RA and SA in the same period.

No similar study was made of coal P, but from some meager data obtained during the course of the general investigation, the authors formed the opinion that this coal will not deteriorate with such rapidity after storage.

In Table 3, are given the original analyses (tabulated earlier), together with those made after intervals of 253 days for coals RA and SA and of 178 days for coal P. The outstanding changes are: reductions in the volatile contents, which range from 0.5 to 2 per cent; reductions in carbon, which for coals RA and SA amount to 2.5 to 3 per cent and for coal P to about 1 per cent; and increases in oxygen, which range from 1.06 to 3.46 per cent.

There is a much greater change in the analyses of coals RA and SA, which are from adjacent mines, than in coal P, which came from a totally different field. The difference in deterioration is evidenced also by the lesser reduction in the agglutinating value of coal P, as shown in Table 2.

As far as the agglutinating value is concerned, the most significant feature of Table 3 is the increase in oxygen content. Only two ultimate analyses were made. Consequently, the variation in the rate at which the oxygen was absorbed is unknown. That the absorption does not occur at a constant rate has been shown by many researches; Davis and Reynolds in *Technical Paper* 409 of the U. S. Bureau of Mines, Bone in his "Coal and Its Scientific Uses," and many other investigators have found that the absorption and retention of oxygen are more rapid during the early period of exposure than during the later period. A straight line does not represent the increase of oxygen with time; the curve rises more rapidly during the first days and tends to flatten out later. Undoubtedly, the coals studied would have shown the same relation had more ultimate analyses been made.

Table 2 shows this characteristic in the reduction of the agglutinating value. The decrease in the value during the first days is much more rapid than during the later part of the exposure, as the last column indicates. For coals SA and RA the reduction

Table 2.—*Agglutinating Values*

Coal	Interval Between Tests, Days	Approximate Time after Mining, Days	Agglutinating Value	Reduction in Agglutinating Value per Day of Interval, Per Cent
First Tests:				
SA.......	0	60	3469	47.8
	54	114	887	
	121	181	488	5.9
RA.......	0	60	3550	
	59	119	817	46.3
	106	166	606	4.5
	131	191	531	3.0
P.........	0	20	3729	
	30	50	2810	30.6
	64	84	2475	9.9
Second Tests:				
SG.......	0	199	2500	
	7	206	894	229.4
	14	213	650	34.9
RG.......	0	199	2580	
	7	206	989	277.3
	14	213	431	79.7

in value per day during the first periods of 54 and 59 days averages 47 g., while the reduction toward the end of the exposure is from 3 to 6 g. per day.

Conclusions

Approximate comparisons were made between the drop in the agglutinating value and the probable increase in oxygen retention, based upon the results of other investigators, and the general forms of the curves were found to be similar. The data are not complete enough to permit final conclusions to be drawn, but the indication appears to be that the rate of loss in agglutinating power follows closely the rate of increase in the oxygen content of the coal. A further and more complete investigation of this feature is warranted. The agglutinating measurement seems sufficiently reliable to give concordant results for such an investigation.

Table 3.—*Moisture-free and Ash-free Basis*

Coal	Interval, Days	Approximate Time after Mining, Days	Proximate Analyses: Volatile Matter, Per Cent	Proximate Analyses: Fixed Carbon, Per Cent	Ultimate Analyses: C, Per Cent	H, Per Cent	N, Per Cent	S, Per Cent	O, Per Cent
SA................	0	60	47.63	52.37	80.47	6.14	1.93	1.00	10.46
	253	313	45.63	54.37	78.03	6.02	1.90	0.97	13.08
RA................	0	60	45.60	54.40	81.35	5.93	2.89	1.11	8.72
	253	313	44.57	55.43	78.04	5.87	2.82	1.09	12.18
P..................	0	20	43.02	56.98	80.73	5.74	1.80	1.14	10.59
	178	198	42.47	57.53	79.89	5.54	1.79	1.13	11.65

Submerged Combustion

(*Continued from page 40*)

duces in this time 5 tons of finished phosphoric acid 110 deg. Tw. concentrated from the 40 deg. Tw. product. Also another installation turns out 3½ tons of concentrated sulphuric acid (R. O. V.) 160 deg. Tw. per week from 60 deg. Tw. chamber acid, or 16½ tons of 144 deg. Tw. acid from 120 deg. Tw. acid. The over-all thermal efficiency of evaporation or concentration in such installations is about 90 per cent, calculated upon the net calorific value of the fuel.

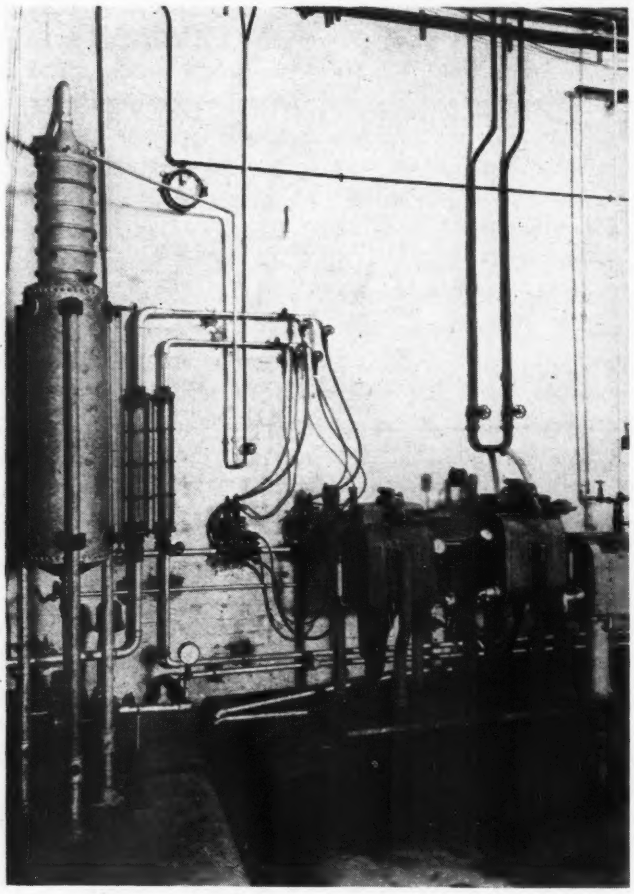


Fig. 7—Installation of Hammond Vortex dyeing drums

Further applications in commercial use, as already indicated, are the polymerisation of linseed oil (by heating to 300 deg. cent.) the melting of white metals such as lead, tin, antimony, silver, and solder, and dyeing and cleaning using, for example, a closed vortex drying drum, having a submerged combustion burner in the circuit with continuous, very rapid travel of the hot liquid through the goods, giving an effective penetration.

In concluding, the author wishes to express his appreciation to Messrs. Submerged Combustion, Ltd., and Mr. C. Featherstone Hammond for kindly allowing full inspection and for the valuable assistance in connection with the preparation of this article, as well as for the illustrations.

Thermal Changes in Water and Steam

(*Continued from page 36*)

steam and $(1-x)=0.8021$ lb. of water present after heating. The initial total heat is $355.33+842.4\times 0.1=439.6$ B.t.u. per lb. The final total heat is $424.2+779.8\times 0.1979=578.5$ B.t.u. per lb. For the initial condition, we have

$$A\ pv=\frac{144\times 200\times 0.2451}{778.6}=9.1 \text{ B.t.u. per lb.}$$

For the final condition, we have

$$A\ pv=\frac{144\times 400\times 0.2451}{778.6}=18.1 \text{ B.t.u. per lb.}$$

Hence, the initial internal energy is $439.6-9.1=430.5$ B.t.u. per lb. and the final internal energy is $578.5-18.1=560.4$ B.t.u. per lb. The heat added is therefore $560.4-430.5=129.9$ B.t.u. per lb.

References

Clausius' textbook on the Mechanical Theory of Heat (translated by W. R. Browne) and Rankine's Manual of the Steam Engine and Other Prime Movers, are of historical interest in discussions on thermal changes in water and steam. More modern textbooks on thermodynamics by Zeuner, Goodenough and others may be consulted.

Combustion Characteristics of Gaseous Fuels

(*Continued from page 30*)

hydrogen in mixed natural gas assists its ignition considerably. The effect of large quantities of moisture in lighting newly constructed furnaces usually makes it difficult to maintain good ignition until the furnace is dried out. A rich mixture seems to aid combustion under such conditions.

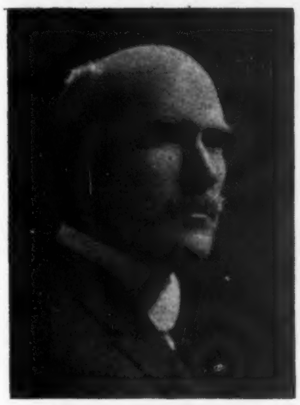
4. *Insulation:* Preventing heat losses from the flame, by radiation or conduction, increases its combustibility. Flames impinging upon cold boiler surfaces often result in incomplete combustion. Burners firing into refractory tunnels completely sealed from air infiltration ignite more readily than those firing through open ports.
5. *Furnace Pressure:* A high draft or strong suction, especially on burners firing through open ports, may pull the flame off the burner such as when applied to boilers. Maintenance of but slight draft or a faint back pressure often renders combustion more effective.

The manufacturers of burners have by actual test determined the capacities and recommended practices for their equipment so that burners can be obtained for any conditions desired that will give highly satisfactory results for a great range of operation, with considerable flexibility and uniform flame characteristics from minimum to maximum fuel consumption.

NEWS

Pertinent Items of Men and Affairs

E. R. Fish Made Hartford Chief Engineer



E. R. FISH

THE Hartford Steam Boiler Inspection and Insurance Company, Hartford, Conn. announced the appointment of Edwards R. Fish as chief engineer of its Boiler Division, effective May 1. Mr. Fish, formerly vice-president of Heine Boiler Company, St. Louis, was made consulting engineer of the Boiler Engineering Department of Combustion Engineering Corporation, New York, when that organization acquired the Heine Company in 1927.

Long a member of the boiler code committee of the American Society of Mechanical Engineers, Mr. Fish is chairman of the sub-committee on unfired pressure vessels. He is also a member of the society's power test code committee and chairman of its sub-committee on boiler testing. He is a former president of the American Boiler Manufacturers' Association, is now a director of the American Uniform Boiler-Law Society and has been on the council of the American Society of Mechanical Engineers.

Mr. Fish is a native of Georgia, received his early technical education at the St. Louis Manual Training School, and graduated with the degree of Mechanical Engineer from Washington University.

•

G. B. Cunningham, Assistant Sales Manager of Federal Phosphorus Company, a division of The Swann Corporation, has been transferred from the home office at Birmingham, Alabama, to the company's New York office, 1239 Graybar Building.

Mr. Cunningham is directing sales of diphenyl, a new basic chemical which finds direct use as a heat transfer medium, particularly in the process industries where accurately controlled temperatures are required.

•

E. A. Doyle, Consulting Engineer of the Linde Air Products Company, New York, was elected President of the American Welding Society at the annual meeting of the society held April 25, 1930.

Utility Investments Exceed $26,500,000,000

More than $26,500,000,000 is now invested in the public utility business in this country, exclusive of steam railroads, by more than 3,000,000 investors, according to the annual public utility survey made by Bonbright & Co., Inc., New York. This figure represents an increase of $1,000,000,000 in the past year. The largest investment in any one branch of public service is in the electric light and power field where the amount is approximately $11,100,000,000. This compares with about $5,353,000,000 in electric railways, $4,557,000,000 in telephone and telegraph companies and $4,750,000,000 in the manufactured and natural gas industry. Approximately $900,000,000 is invested in privately owned water supply facilities . An interesting feature of the report is that the total investment for electric railways decreased slightly during the year.

•

Combustion Engineering Corporation, New York announces the appointment of A. C. Weigel as Manager of its Boiler Department, effective May 15. Mr. Weigel was formerly Assistant General Sales Manager of the Company.

•

The Dampney Company of America of Hyde Park, Boston, Mass., announces the appointment of R. G. Ingram to supervise its Sales Agencies in the Middle West. Mr. Ingram will maintain his headquarters at One La Salle Street, Chicago.

•

The Brown Instrument Company, Philadelphia, announces the consolidation of its Chicago Sales Office and Midwestern Factory Branch in new quarters located at 155 East Superior Street, Chicago, Illinois. Practically double the former space has been provided in line with the growth of business throughout the Middle West.

•

Five-Year Coal Research Program For Carnegie Institute of Technology

Contributions amounting to $425,000 have been pledged to finance a five-year coal research program at Carnegie Institute of Technology, Pittsburgh, according to a recent announcement by Dr. Thomas S. Baker, president.

The Buhl Foundation will contribute $50,000 for the equipment of a research laboratory and $25,000 a year for five years. The United States Steel Corporation, General Electric Company, Koppers Company, New York Edison Company, Standard Oil Company of New Jersey and the Westinghouse Electric and Manufacturing Company will jointly contribute $50,000 annually for the five year period for the operation and maintenance of the laboratory.

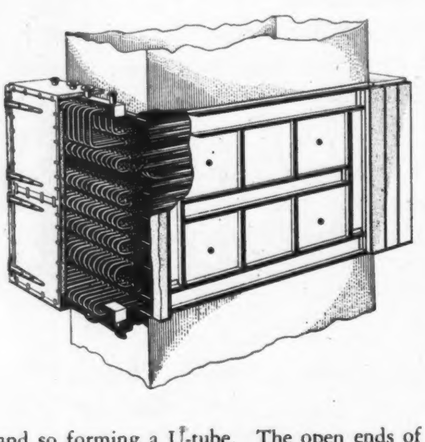
NEW EQUIPMENT

of interest to steam plant Engineers

New Extended-Surface Economizer

AFTER several successful experimental installations the C-E Economizer, Fin-tube type, has been placed on the market by Combustion Engineering Corporation, New York. This economizer has been developed to meet an insistent demand from the power industry for a more efficient and compact unit capable of wider application. This economizer can be installed in considerably less than half the space required for a straight, plain-tube economizer of equivalent heating surface. The principal features, as shown in the illustration below, are the external return bends, the internal return bends, the tube arrangement and the use of finned tubes which provide additional heat-absorbing surface.

The heat-absorbing elements are constructed by connecting a U-bend to two straight tubes



and so forming a U-tube. The open ends of each U-tube are connected serially by return bends located outside the end-plates, to the tubes directly above and below. The adjacent vertical tube sections are arranged so that the open ends of the U-tubes alternately enter one end and the other of the economizer casing. The water circulation is separated into two circuits, one running through the U-tubes connected by the return bends at one end of the economizer and the other through the U-tubes connected by return bends at the opposite end. A distinct advantage of the two separate water circuits is that the water flows through only one-half the tube distance as compared with the plain-tube, single-circuit type of economizer. With extended surface in the form of fins, the tube length is still further reduced resulting in such a decrease in the frictional resistance that the water pressure drop is about one-fifth that of the plain-tube, single-circuit type of economizer. Both circuits are served by common inlet and outlet headers.

The compactness of the unit is derived principally from the fin-tube design which reduces the tube-length per square foot of heating surface, and the return bend arrangement which permits the tubes to be nested closely together so that the space they occupy is less than half the space required for a straight tube economizer of equal heat-absorbing surface. The end plates are designed to permit their being quickly and easily removed for the inspecting and cleaning of the tubes.

Smoke and Soot Washer

REGARDLESS of the method of firing, each steam plant chimney contributes to air pollution. With stoker firing, the emissions include fine cinders. With pulverized fuel firing, fly-ash is discharged, while soot is thrown out when fuel oil is burned. The release of sulphur fumes is common to all fuels which contain sulphur, and, with faulty combustion, smoke may be produced with any fuel.

There is a rapidly increasing demand for some simple and reliable method of minimizing air pollution and to meet this need the American Smoke and Soot Washer Company, Inc., 55 West 42nd Street, New York, has developed a spray-type washer which is shown below.

The washer consists essentially of two cones, the first A being directly on top of the existing stack. A second cone B, having a rounded top and of a diameter somewhat larger than that of the stack, is supported above the top of the stack. Two water spray rings are located inside of the top cone, near its lower edge and these rings are provided with flat spray nozzles so spaced as to produce a double annular curtain of water completely surrounding the top of the stack.

The gases pass upward in the stack until they are deflected by the top cone B which directs them through the double spray, thence through the annular space between the upper and lower cones and to the atmosphere, as shown by the arrows.

Circular baffles are provided to make certain that all of the gas passes through the double spray and that none short circuits through the spaces between adjacent nozzles. The spray rings are of copper and the nozzles are of tobin bronze. Corrosion resisting metal is used for the body of the washer and several coats of protective paint are applied.

The drain C leads to a tank which is provided with screens and baffles to catch the solid matter that is washed out of the stack gases. The water is then recirculated by a motor-driven centrifugal pump which maintains a pressure of 20 to 30 lb. at the nozzles.

The operation of the nozzles may be observed from the walkway which surrounds the washer.

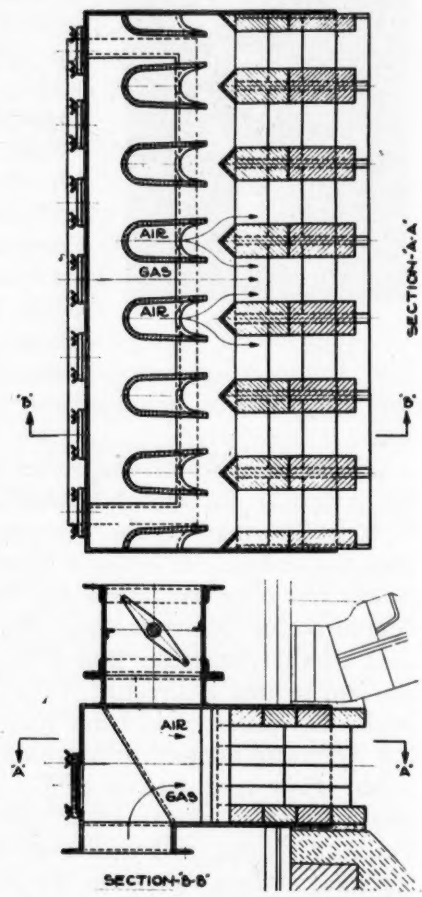
With minor changes in design, the washer is also applicable to concrete or brick chimneys.

New Gas Burner

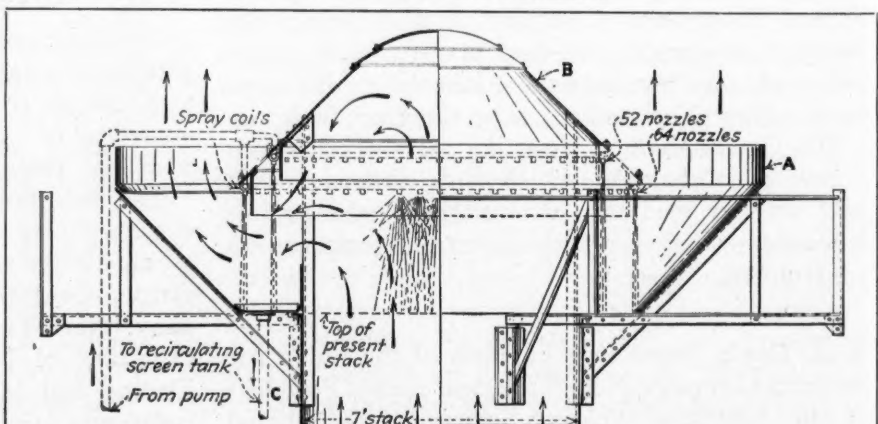
THE Freyn Engineering Company, Chicago, Illinois, has announced a new gas burner which is applicable to steam boiler use. The illustrations below show both vertical and horizontal cross sections of this new pressure burner.

The salient features of the Freyn burner are:

1. Multiple gas and air ports provide intimate mixing of gas and air.
2. Gas and air ports are refractory lined, thereby presenting no metal surface to furnace temperatures.
3. Arranged to be operated by any system of automatic combustion control.
4. Suitable for any gas temperature or pressure and for any air temperature or pressure.
5. Built to any desired capacity and to suit any furnace width.



Access doors are provided in the front panel of the burner, opposite each opening into the furnace.



REVIEW OF NEW TECHNICAL BOOKS

Any of the books reviewed on this page may be secured from In-Ce-Co Publishing Corporation, 200 Madison Avenue, New York

Elements of Engineering Thermodynamics

By Moyer, Calderwood and Potter

THIS book has been widely used as a standard text on the subject. The new edition is the fourth to be published and has been thoroughly revised and brought up to date. The aim behind much of the revision has been to treat the fundamentals in such a way that they will be thoroughly understood, not merely memorized.

The phases of the subject covered are,—thermodynamic principles and definitions; properties of perfect gases; thermodynamic processes of gases; cycles of heat engines using gas; properties of vapors; entropy; thermodynamic processes of vapors; vapor cycles; flow of fluids; application of thermodynamics to compressed air and refrigerating machinery.

New material includes the theory of the hot air engine and internal combustion engine cycles. The appendix includes logarithmic tables, the properties of gases, the properties of steam, ammonia, sulphur-dioxide and carbon dioxide; also a representative list of reference books.

The book is 6 by 9 overall and contains about 200 pages. Price $2.50.

Heat Power

By Norris and Therkelsen

THIS volume is intended to serve as an introductory course in the principles of heat power for students in engineering. It is based on the premise that today everybody knows something about the principles of operation of the internal combustion engine and this assumed knowledge is used as a starting point for the development of the fundamentals of heat power. The authors have therefore deferred the presentation of steam power plant machinery and equipment until the more familiar internal combustion engine has been covered, in the thought that this arrangement facilitates the approach to thermodynamics.

Throughout the text fundamental principles rather than practice or mechanical details are emphasized. Empirical formulas have been avoided and insofar as possible rational formulas have been developed from basic facts. Although the treatment of the subject is necessarily mathematical, mathematics has been used as a tool and not for the purpose of developing mathematical agility. Examples are worked into the text and a series of study problems are placed at the end of each chapter.

As already indicated, the first part of the book covers internal combustion engines of all types, followed by a discussion of the principles of combustion, work and power, heat and work, and the various cycles. The second part of the book pertains to various types of steam engines, steam turbines, condensing equipment, steam boilers, boiler fuels and furnaces, and boiler performance.

This book is thoroughly up to date, as indicated by the fact that the section devoted to steam plant equipment contains illustrations and descriptions of the most modern stoker and pulverized fuel furnace and boiler arrangements.

Including a comprehensive index, there are 375 pages. The book is substantially bound in stiff covers, 6 by 9 overall. Price $3.50.

Piping Hand Book

Walker and Crocker

THIS book represents a very comprehensive compilation of reference information on piping. The following list of chapter headings indicates its scope: Definitions, Formulas and Tables; Fluids—Properties of Fluids; Metallurgy of Piping Materials; Pipe, Valves and Fittings; Heat Insulation; Hangers and Supports; Expansion and Flexibility; Steam Power Plant Piping; Building Heating Systems; Plumbing Systems; Underground Steam Piping; Water-Supply Piping; Fire-Protection Piping; Oil Piping; Gas Piping.

The chapter on expansion and flexibility warrants particular mention. This subject, which has engaged the attention of numerous investigators, is fully covered, and simple methods are given for computing the expansion stresses and anchor thrusts in pipe lines. The chapter on steam power plant piping also contains some especially valuable information.

The data presented on each phase of the subject is well arranged and complete. Numerous examples are given to facilitate the use of the information and formulas presented.

This book is attractively bound in semi-flexible fabrikoid covers, 5 by 7¼ overall and contains 763 pages. Price $5.00.

NEW CATALOGS AND BULLETINS

Any of the following publications will be sent to you upon request. Address your request direct to the manufacturer and mention COMBUSTION Magazine

Boiler Water Conditioning

"Controlled Results in Boiler Water Conditioning" is the title of a new bulletin which describes the work of Dr. R. E. Hall and his associates of Hall Laboratories, in cooperation with the United States Bureau of Mines. The increased size of steam units, the higher pressures and temperatures, and the higher rates of driving, have presented a complex problem of feed water conditioning. The present bulletin outlines what is described as the most extended and elaborate investigation ever undertaken in connection with boiler water conditioning. 16 pages, 8½ x 11—Hagan Corporation, Pittsburgh, Pa.

Combustion Control

Bulletin No. 660 presents L & N Metered Combustion Control equipment which is offered to provide automatic control of the rate of combustion in accord with the demand for steam, to maintain uniform header pressure with efficient combustion and correct furnace pressure. With proper control, each furnace is supplied with the quantity of fuel that is required for the load on the boiler, and the quantity of air that will insure minimum loss due to incomplete combustion and the escape of heat in the exit gases. With L & N Control, metered quantities of fuel and air are supplied automatically to meet these conditions. 32 pages and cover, 8½ x 11—Leeds and Northrup Company, 4901 Stenton Avenue, Philadelphia, Pa.

Draft Gages

Bulletin No. 12 presents the Ellison Pointer Draft Gage (Dial Type). This is a new model and is available in one, two and three pointer types. The gage is of rugged construction and has a powerful movement mounted on knife edge bearings. The gage is designed for draft measurement, minus, plus, or differential and for air and other gases up to five inches water pressure, using oil. For higher readings, mercury is used. The construction is described in detail and many illustrations are included. 8 pages, 8½ x 11—Ellison Draft Gage Company, 214 West Kinzie Street, Chicago, Ill.

Dust Recovery

A new booklet "Dust Problems" approaches the subjects of dust nuisance and dust recovery in a remarkably clear and comprehensive manner. The successful solution of a dust problem is largely dependent on the proper selection of dust collecting equipment. Each case presents many individual problems which are better analysed by considering each of the following factors: (1) the application; (2) dust characteristics; (3) volume and temperature of gases; (4) dust loading of the gases; (5) relative humidity of the gases; (6) chemical analysis of the gases. Many charts, graphs and tables are included which present information not readily available elsewhere. 70 pages and cover, 8½ x 11—Dust Recovery, Inc., 15 Park Row, New York.

Feed Water Heaters

Bulletin S-18 describing Swartwout Feed Water Heaters has been reprinted. The Junior Heater is designed for small plants whose boiler capacity does not exceed 250 hp. For larger capacities the Swartwout All Service Feed Water Heater is offered. Exhaust steam is used to heat the boiler feed water up to 208 to 212 deg. fahr. before it is fed to the boiler. An oil separator, built into the heater removes oil from the exhaust steam thus making the surplus steam or water available for any use. The operation is automatic, simple and reliable. Numerous illustrations show the details of design and principle of operation. Dimension sheets and tables are included. 28 pages, 8½ x 11—The Swartwout Company, Cleveland, Ohio.

Heat Resisting Enamels

Ce-Co Enamels for engines, machinery, pipe lines cement floors and general utility are presented in a new bulletin. Ce-Co Engine enamel is heat resisting and ordinary shades stand temperatures up to 250 deg. fahr. For higher temperatures Ce-Co Interior Heat Resisting Paint is recommended, the lighter shades of which are satisfactory up to 300 deg. fahr., while the dark shades will withstand temperatures up to 400 deg. fahr. Ce-Co Cement Floor Enamel penetrates the pores of the cement and provides a dustless, oil and waterproof finish. A wide range of special enamels is available to meet practically every industrial plant need. Suggested color schemes are included to distinguish pipe lines. Cheesman-Elliott Company, Inc., 639 Kent Avenue, Brooklyn, N. Y.

Pump Governor

The Copes Type DS Pump Governor is described in folder No. 111. This device is presented as a simple, rugged and dependable governor which is designed for a maximum excess pressure of 75 lb. and can be installed on simplex, duplex or triplex pumps, and on turbine or motor driven centrifugal pumps. It is suitable for excess pressure service in boiler feeding; differential reducing valve service on motor-driven centrifugal pumps; relief valve service on belt or gear driven pumps. Numerous illustrations show construction details. 4 pages, 8½ x 11—Northern Equipment Company, Erie, Pa.

Refractory Gun

The Quigley Refractory Gun uses a premixed plastic refractory material composed of Hytempite, a refractory cement, mixed with crushed old firebrick. This plastic mixture when shot at high velocity, will stick to either a hot or cold wall owing to the force of its application, in cases where troweled or rammed-in applications might fail to hold. The gun has a wide field of use in the repair and maintenance of furnace linings, including hot patching and surface coating. 12 pages, 3½ x 6½—Quigley Furnace Specialties Co., 56 West 45th Street, New York.

Scotch Marine Boilers

New Bulletin No. 216 describes the Leffel line of Scotch Marine Boilers. These boilers are self contained and portable and are built to A.S.M.E. code specifications in a wide range of sizes from 6 hp. to 200 hp. Various types of firing equipment are shown including, hand firing, stoker firing, oil or gas firing, and wood firing. The Leffel Underfeed Stoker, especially adapted to Scotch Marine and other internally fired boilers is illustrated and briefly described. Specifications and data are included. 24 pages and cover, 8½ x 11—The James Leffel & Co., Springfield, Ohio.

Small Stoker

The Whiting Stoker is presented in folder H-47. This stoker represents an entirely original design, exclusively developed for small boilers, from 25 hp. to 250 hp. and may be installed with a minimum setting height. The movement of the fuel bed is horizontal, making it easy to maintain an even fuel bed of uniform thickness, hence the correct application of air at low static pressure is possible. The ash and refuse are continuously and automatically discharged, as formed, from the rear of the grates to the ash pit below. 4 pages, 8½ x 11—Whiting Corporation—Harrington Division, Harvey, Ill.

Speed Reducers

Jones Herringbone Speed Reducers are described in a new catalog No. 45. These speed reducers are available in both single and double types, are fully enclosed and self contained. The gears are accurately generated, the housings are particularly rugged and large roller bearings are used throughout. A large oil reservoir in the lower portion of the housing provides for copious bath lubrication. Tables and data sheets are included. 80 pages and cover, 8½ x 11—W. A. Jones Foundry and Machine Co., 4401 Roosevelt Road, Chicago.

Underfeed Stoker

The Iron Fireman, an automatic underfeed stoker for boilers up to 200 hp. is illustrated and described in a new catalog, No. 30. Five charts, in color, illustrate the advantages of underfeed firing while twelve sketches are presented to show the application of this stoker to a wide range of boilers and setting conditions. The details of construction are well shown and complete specifications and a dimension chart are included. 16 pages and cover, 8½ x 11—Iron Fireman Manufacturing Company, Portland, Oregon.

Water Cooled Furnace Wall

Drake Armor-Clad Water Walls are presented in Bulletin No. 105. The construction consists of a continuous wall of metal blocks cast on standard seamless boiler tubes which are rolled into headers and connected into the boiler circulation. The details of construction and a typical installation are illustrated. 8 pages, 8½ x 11—Drake Non-Clinkering Furnace Block Co., 5 Beekman Street, New York.

NOTICE

Manufacturers are requested to send copies of their new catalogs and bulletins for review on this page. Address copies of your new literature to

COMBUSTION
200 Madison Ave., New York

COMBUSTION

GENERAL INDEX OF EDITORIALS AND ARTICLES

(Vol. 1, No. 1, July, 1929, to and including Vol. 1, No. 12, June, 1930)

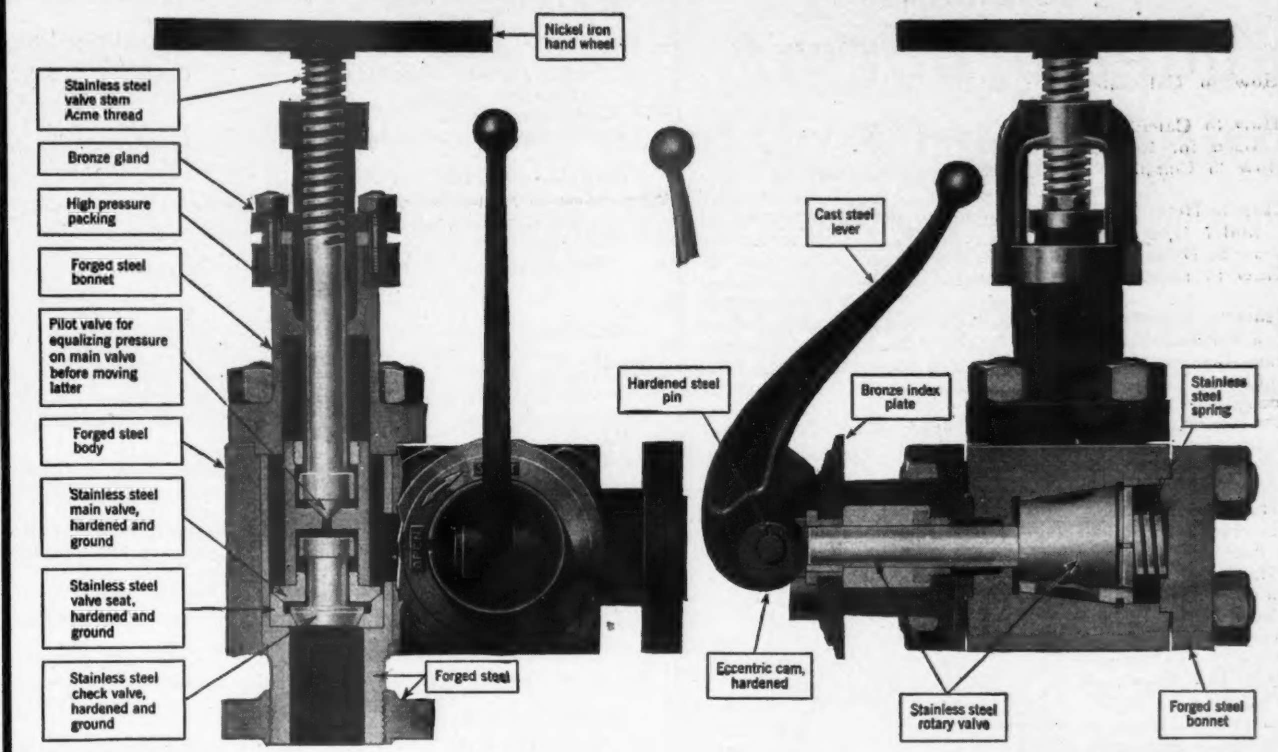
Feature Editorials—

Editorials—

Articles—

Authors—

(*Continued on page* 54)



OPEN or SHUT

No Wire Drawing, Cutting or Scoring

THE sealing valve and the rotary gate valve of the Cochrane One-piece, Forged-steel Tandem Blow-off Valve are opened and closed only when there is no flow—during the actual blowing down they are in protected positions, out of the path of the discharge. A separate check disk takes all the wear of opening and closing under flow. In the operation of the rotative valve, it is first loosened from its seat before being rotated, avoiding abrasion by grit. All valve parts are made of stainless steel, hardened and ground.

This valve gives entirely satisfactory service under modern high pressure, high temperature conditions.

Ask for Bulletin IC-1524

COCHRANE CORPORATION

3160 North 17th Street, Philadelphia, Pa.

463

GENERAL INDEX

(*Continued from page 52*)

T. A. Marsh Heads Stoker Company

T. A. MARSH

T. A. Marsh was made president of the Modern Coal Burner Company, a subsidiary of the Peabody Coal Company, Chicago, on May 1.

In combustion circles Mr. Marsh is widely recognized as an authority on coals and stoker application. For the past seven years he has been western engineer and district representative of the Combustion Engineering Corporation, and before that time he served for ten years as chief engineer of the Green Engineering Company.

The Modern Coal Burner Company manufactures stoker equipment for small boilers and it is said that an enlargement in the sales and manufacturing activities of the company is behind the appointment of Mr. Marsh. The sales and engineering divisions of the company will be located in new quarters at 3733 Lincoln Avenue, Chicago, Illinois.

•

The Edward Valve & Manufacturing Company, East Chicago, Indiana, has appointed the Taubman Supply Corporation, Tulsa, Oklahoma, its sales representative in the Oklahoma and northern Arkansas districts.

•

The Springfield Boiler Company, Springfield, Illinois, announces that A. E. Duram has joined the Springfield general sales organization and is cooperating with the various district offices in strengthening and extending the company's sales activities.

Two 160,000 kw. Generators for Brooklyn Edison Company

Matthew S. Sloan, president of the New York Edison Company and associated companies, has announced that the General Electric Company has been given a contract to build for the Hudson Avenue Station of The Brooklyn Edison Company, two turbo-generators of 160,000 kilowatts (215,000 horsepower) capacity each to meet the general growth of load on the system of five companies of which he is president.

The total cost of the generators, boilers and other necessary equipment will be $18,000,000. Both machines are expected to be in operation in 1931. They will be of the most powerful single-shaft, single-unit design developed to date. The only other 160,000 kilowatt single-shaft, single-unit turbo-generator in the world is located in the East River Station of The New York Edison Company.

Standard Smoke Ordinance Proposed

Because of the increasing importance of the smoke problem in American Cities, the United States Bureau of Mines has reprinted the "Proposed Standard Smoke Ordinance" which was prepared by a joint committee comprised of representatives of the American Society of Heating and Ventilating Engineers, the Stokers Manufacturers' Association, the American Civic Association, and the Fuels Division of the American Society of Mechanical Engineers, and which was originally printed in Mechanical Engineering, May, 1924.

Copies of this reprint, designated as Information Circular 6262, may be obtained from the United States Bureau of Mines, Washington, D. C.

•

The American Society for Testing Materials will hold its thirty-third annual meeting, June 23 to 27 at the Chalfonte-Haddon Hall, Atlantic City, N. J.

A comprehensive program of technical papers and committee reports has been arranged.

•

The Smoke Prevention Association will hold its Twenty-Fourth Annual Convention in Newark, New Jersey, June 24 to 27 inclusive; headquarters Hotel Robert Treat.

Arrangements have been made for inspection trips to points of interest in Newark and the surrounding territory. A most interesting program has been arranged which will afford those in attendance an opportunity to learn the latest development in smoke prevention and fuel conservation work.

•

The National Board of Boiler and Pressure Vessel Inspectors will hold its eighth Annual Meeting at the Hotel Patten, Chattanooga, Tenn., June 17, 18 and 19. A symposium on Welded Boiler Drums and Riveted Boiler Drums is included in the program.

Inspection trips will be made to the various boiler manufacturing plants in the Chattanooga district.

Correction

In the May issue of COMBUSTION, Dr. R. E. Hall contributed a discussion of A. A. Markson's paper "Development of a High Pressure System for Boiler Water Conditioning" which paper was published in our April issue.

In the second column of page 46, second paragraph, of Dr. Hall's discussion, there appears the following:

> "By removal of the bicarbonate by precipitation with lime, a reduction in total solids of 35 per cent or more is effected."

This statement should be corrected to read 30 per cent, instead of 35 per cent.

$900,000,000 Expansion Program For Electric Power Industry

An increase in the 1930 construction programs of electric light and power companies, was reported to President Hoover by Matthew S. Sloan, president of the National Electric Light Association in a letter of April 29th. Last November, this year's expansion program was reported as $865,000,000 but added projects will increase the total to probably $900,000,000.

Mr. Sloan's letter to President Hoover follows:

"Within the last week I have again secured progress reports from electric light and power companies of the status of work in carrying out the programs for new construction and expansion of facilities of which you were advised at the conference in the White House on November 27, 1929.

"Reports by telephone and telegraph are in hand from executives of companies representing 80 per cent of the total to be expended.

"The new construction program of the electric light and power companies is progressing according to schedule and no curtailment or slowing down is reported in this program; on the contrary, in several cases projects have been added which will result in a revision upward, amounting to an increase of thirty or forty million dollars.

"The program for the electric light and power companies as announced to you was $865,000,000 and the information in hand indicates that this will probably reach $900,000,000.

"You may also be interested in information on the output of electricity because of its value as indicating general business conditions.

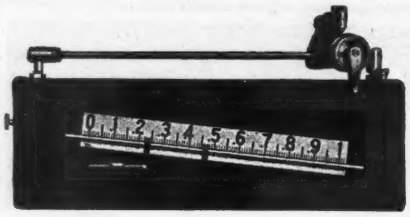
"During the entire period since the first of the year, output of electricity by the electric light and power utility companies has maintained levels above those of corresponding weeks in 1929.

"The output for January, February, March and April to the 26th of the month, has been 5.5 per cent, 2.6 per cent, 3.0 per cent and 1.8 per cent, respectively, above 1929.

"The output for these same months is, however, 19.8 per cent, 11.6 per cent, 14.7 per cent and 18.3 per cent respectively above the levels for 1928.

"The rate of increase in output of electric energy during the greater part of 1929 was abnormally high, due in large part to accelerated industrial activity. For this reason we consider the levels of electric energy output which have been maintained this year as indicative of strong demand for electric service.

"Although there is falling off in industrial power in localized areas, this has been more than offset, taking the country as a whole, by the remarkable increases which are going on in the use of electricity in homes. The use of electricity in households in the United States is running about 15 per cent above the levels for 1929."



ELLISON DRAFT GAGES The Entering Wedge To Boiler Room Efficiency

Ellison Inclined Draft Gage

Not Built to a Price

The Ellison inclined tube gage is the original—not an imitation. It is a masterpiece in design, construction and accuracy and is built by an organization of draft gage engineers ever seeking the ideal. A new feature has been added comprising a removable plug for cleaning the indicating tube.

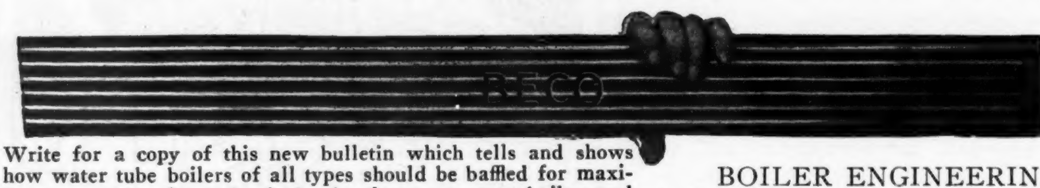
Bulletin Nine-A describes this remarkably accurate and well constructed gage.

ELLISON DRAFT GAGE COMPANY

214 West Kinzie Street Chicago

Just off the press!—a new bulletin entitled:—

"How BECO Baffles Modernize Old and New Water Tube Boilers"



This BECO Sheet Metal Separator placed down each diagonal alley separates the plastic and eliminates cracking and breaking. Positive expansion joints are created. Hot gases, worth dollars to you, cannot get through.

Write for a copy of this new bulletin which tells and shows how water tube boilers of all types should be baffled for maximum money saving. Send sketch of your present boiler and give data. Our engineers will be glad to quote and will estimate the money BECO Baffles will save for you.

BOILER ENGINEERING COMPANY

24 Commerce St. Newark, N. J.

CANADA: F. W. Pennock & Co., Montreal, Quebec.

GREAT BRITAIN: Detrick Arch Co., Ltd., London, W.C.1

Steady Growth *of* Engineering Endorsement

Regular re-orders year after year from 90-95% of our customers can have but one meaning:—

APEXIOR protective coating has *proved its value* in preventing boiler corrosion to the complete satisfaction of hundreds of public utilities, and industrials.

Write for Bulletin No. 1180

APEXIOR REG. U.S. PAT. OFF.

***The* DAMPNEY COMPANY *of* AMERICA**

HYDE PARK BOSTON, MASS.

REFRACTORIES

Fire Clay

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Magnesite

High Alumina (Diaspore)

High Temperature Cements

General Refractories Company

106 South 16th St., Philadelphia, Pa.

District Offices: Boston, Buffalo, Chicago, Cleveland, Detroit, Indianapolis, New York, Pittsburgh, St. Louis, San Francisco

Representatives: Seattle, Montreal, Havana, Cuba

4187

Further Reduction Ordered in California Oil Production

As a step toward further stabilization of the California oil industry, an agreement to reduce production to 596,000 barrels a day was reached May 14 by a committee representing the general operators of the state. For the past few months the daily production has been limited to 609,000 barrels.

The new cut in production was decided upon after the operators' committee had heard the report of eleven producing companies as to the status of the oil industry, according to an announcement by H. R. McMillan, president of the California Oil and Gas Association.

The new curtailment figure is expected to remain in force for six months, at which time a new figure will be fixed according to conditions then prevailing.

•

T. G. Hart has been made General Sales Manager of the Terry Steam Turbine Company and will be located at the company's home office Hartford, Conn. Mr. Hart has been associated with the Terry Company since 1919 and for the past several years has been manager of the Chicago office.

•

The Terry Steam Turbine Company also announces the appointment of S.O. Maxwell as district manager of the New York office at 90 West Street, New York City. Mr. Maxwell has been associated with the Terry Company since 1925 and during the past several years he has served as assistant New York manager.

•

Ford, Bacon & Davis, Inc., engineers, New York City, announce the appointment of Page Golsan as business manager.

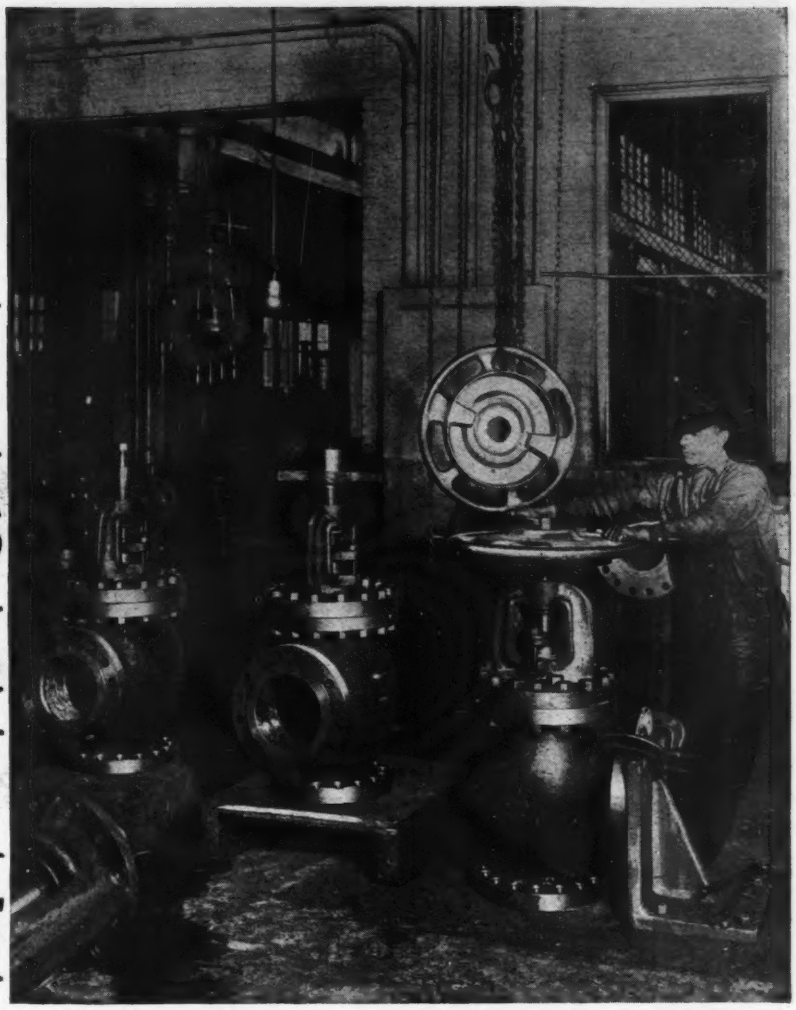
Mr. Golsan was formerly vice-president and general manager of the Great Western Portland Cement Company and has become associated with Ford, Bacon & Davis to supervise a phase of the company's activities in the natural gas field. This organization recently completed the largest and longest high pressure pipe line in the world, extending from the gas fields of Louisiana to Atlanta and Birmingham.

•

The International Railway Fuel Association held its annual meeting at the Hotel Sherman, Chicago, May 6 to 9 inclusive. An attendance of 2,012 is reported.

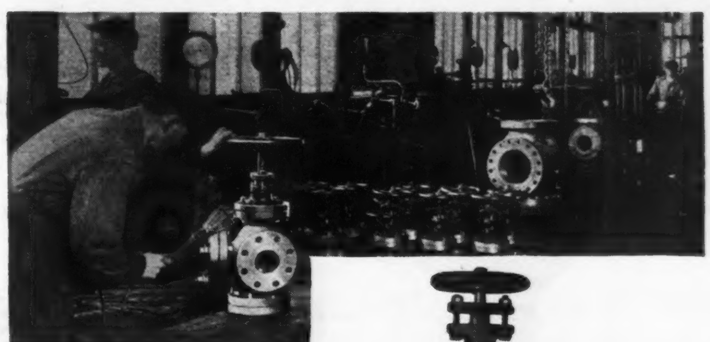
At the closing session, the railroad members of the Association elected the following officers for the ensuing year: President, C. H. Dyson, fuel agent, Baltimore & Ohio, Baltimore, Md.; vice-president, W. G. Black, mechanical assistant to the president, Chesapeake & Ohio, Cleveland, Ohio; vice-president, C. I. Evans, chief fuel supervisor, Missouri-Kansas-Texas, Parsons, Kan.; vice-president, J. M. Nicholson, fuel conservation engineer, Atchison, Topeka & Santa Fe, Topeka, Kan.

THREE LEADERS THAT PAY THEIR WAY IN ANY POWER PLANT



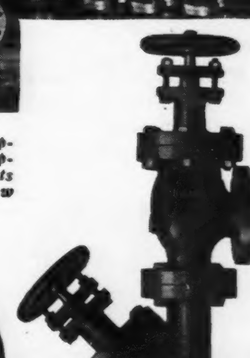
These 10" No. 705 non-return valves are installed in a large oil refinery. Edward (patented) impactor handwheels are used for closing against boiler tests pressures.

Permanently dependable for superheated steam, feedwater or blowdown. Edward valves are confined to certain clearly defined lines—for a widely growing market. Non-return valves to assure automatic control between boiler nozzle and header—drumhead stop-check valves of proved reliability for the feedlines—blowoff valves of satisfying freedom from leakage—these are three leaders that pay their way in any power plant. There is a type for every piping layout.



Hydrostatic pressure is being applied to No. 548, drumhead stop-check valve—water and air tests are made both above and below the disc.

THE EDWARD VALVE & MANUFACTURING CO.
EAST CHICAGO - - - INDIANA

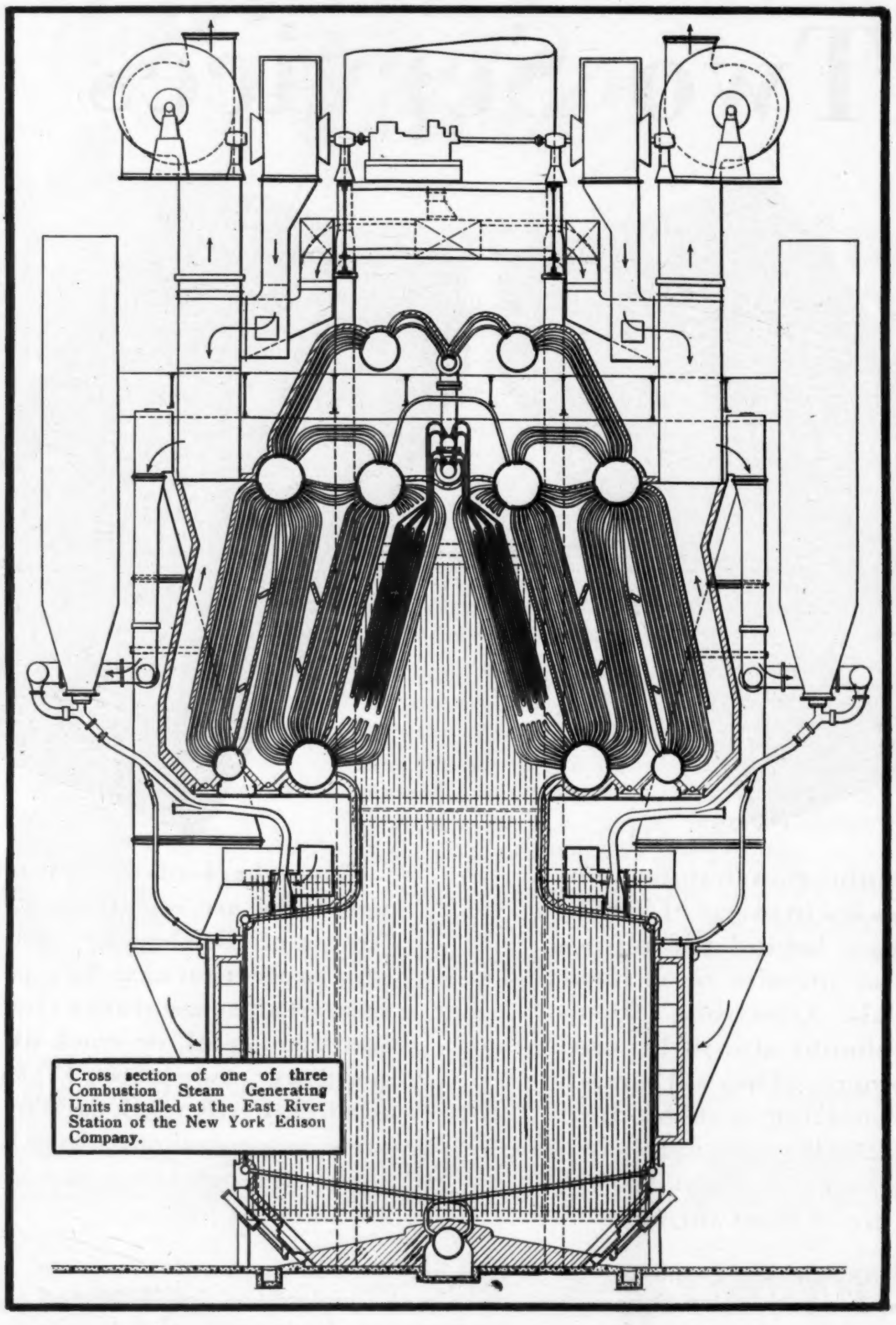


Edward blowoff valves are made for pressures up to 2000 lbs. Cut shows Valves Nos. 341 and 343, which save money in the 250# W.S.P. range.

EDWARD VALVES

TRADE MARK REG. U. S. PAT. OFFICE

This boiler unit has oper-

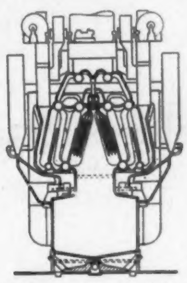


Cross section of one of three Combustion Steam Generating Units installed at the East River Station of the New York Edison Company.

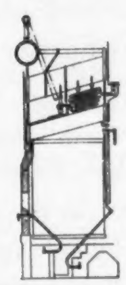
LOW or HIGH

Pressures—Temperatures—Capacities

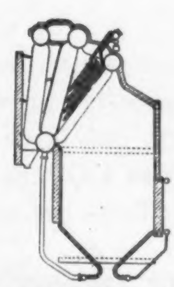
A few notable Elesco superheater installations made during the past year.



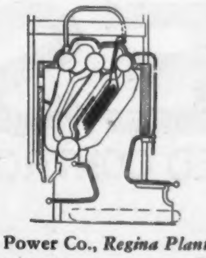
New York Edison Co., *East River Station*
Steam temperature............710 deg. F.
Pressure..................425 lb. per sq. in.
Steam generation.........800,000 lb. per hr.
1,250,000 lb. per hr. maximum obtained to date.



Union Electric Light and Power Co., *Venice Station*
Steam temperature..............700 deg. F.
Pressure...................375 lb. per sq. in.
Steam generation.........235,000 lb. per hr.



Broad River Power Co., *Parr, S. C., Station*
Steam temperature..............680 deg. F.
Pressure...................300 lb. per sq. in.
Steam generation.........200,000 lb per hr.



Saskatoon Power Co., *Regina Plant*
Steam temperature..............725 deg. F.
Pressure...................400 lb. per sq. in.
Steam generation..........85,000 lb. per hr.

—Elesco

Basic Fundamental Principles Remain the Same

ALTHOUGH pressures, temperatures and capacities in power-plant practice have followed a rising trend since this company's formation, the extensive application of Elesco superheaters, both to normal and extreme conditions, conclusively has proved that adherence to pioneer basic Elesco design principles gives consistently excellent results. These fundamental basic principles are:

1. High steam velocity.
2. Multiple-loop, single-pass superheater unit construction.
3. Perfect steam distribution in the headers by locating steam inlet and outlet on opposite ends.
4. Location of headers outside of the boiler setting wherever possible.
5. Small-diameter tubing with several sizes available.
6. Detachable superheater units.
7. Minimum number of joints.

THE SUPERHEATER COMPANY

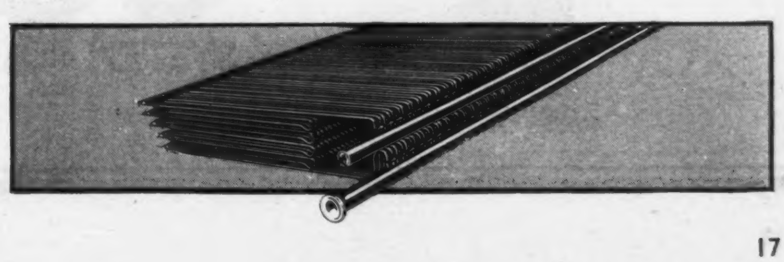
60 East 42nd Street, NEW YORK

Peoples Gas Building CHICAGO — ELESCO — Union Trust Building PITTSBURGH

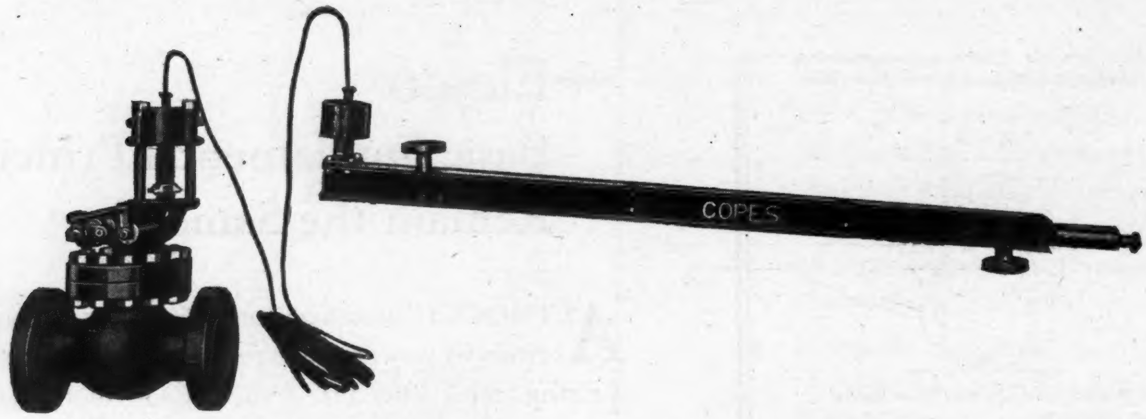
CANADA: The Superheater Company, Limited, Montreal

Birmingham, Charlotte, Denver, Houston, Kansas City, Memphis, New Orleans, San Francisco

A-453



FOR 1400 POUNDS PRESSURE AT SAN ANTONIO



The Problem

To provide effective, economical feed water regulation on a Connelly cross-drum sectional-header boiler operating at 1400 pounds steam pressure. Equipment will include a Foster-Wheeler superheater, air heater, economizer and steam reheater. Maximum evaporation will be 215,000 pounds per hour, with a steam temperature of 810 degrees F. Feed water pressure will be 1600 pounds, with a temperature of 338 degrees F.

The Solution

The turbine-driven boiler feed pump is being equipped with a COPES Type DS Governor suitable for 1400 pounds steam pressure. A COPES Type SDS Differential Valve will be installed in the discharge line from the motor-driven pump. The boiler is being equipped with a COPES Type BIR Regulator, with the new COPES unit for liquid transmission of power as illustrated above. This leak-proof, quick-acting unit was originally designed for the 685-pound pressure boiler of Unit 4 at Waukegan.

Again the COPES System of Boiler Feed Control is chosen for a 1400-pound pressure installation—this time by United Engineers & Constructors for the new addition to Station B of San Antonio (Texas) Public Service Co.

COPES has undivided responsibility from the feed pumps to the boiler. The correct differential water pressure will be maintained in the feed line by a COPES Type DS Governor installed in the steam line to the turbine-driven pump, or by a COPES Type SDS Differential Valve installed in the discharge line from the motor-driven pump. Water will be fed to the boiler in accordance with load demands by the regulator illustrated above—a COPES Type BIR, arranged for liquid transmission of power from the thermostat to the valve.

Alert designers and operators demand accurate control from simplified equipment. COPES engineers provide it. Regardless of your operating pressure, they give you a scientific service plus modern, *simplified* COPES equipment tailored to your specific needs. Facts on request.

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SYSTEM OF BOILER FEED CONTROL

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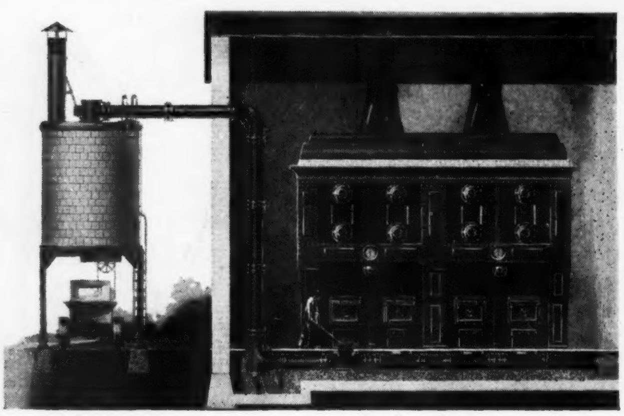
HAGAN STEAM JET AND VACUUM ASH CONVEYOR SYSTEM



The accumulated improvements gained from over 400 plant installations are concentrated in the design of the Hagan Steam Jet and Vacuum Conveyor — the most efficient and economical system of ash removal ever developed.

Operation is extremely simple. The fireman opens a steam valve, removes the intake plug — rakes the ashes or soot into the intake openings where a powerful suction, created by steam jets in the conveyor system, carry the ashes or soot rapidly out of the boiler room to the receptacle or dump.

The cost of installation is surprisingly low because no expensive changes are necessary in the boiler room — maintenance is practically nil as there are no moving parts to get out of order. And it assures a neat, clean boiler room at all times.

Descriptive literature sent upon request.

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